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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VII.

No. I.—JANUARY, 1910.

ORIGINAL ARTICLES.

I.—On Olivine Nodules in the Basalt of Calton Hill, Derbyshire.

By H. H. Arnold-Bemrose, J.P., Sc.D., F.G.S.

(PLATES I AND II.)

Introduction.

THE object of this paper is to place on record the occurrence of olivine nodules in a British basalt which, though closely allied in structure to some of the Tertiary basalts of the Continent, belongs undoubtedly to the Carboniferous age. Olivine nodules frequently occur in the Continental basalts and have been considered by some writers as inclusions of peridotites, but by others as segregations from the magma.

I can find no description of olivine nodules from any British basalt in which the olivine is in a fresh condition. The nearest approach to such a nodule is that described by Mr. S. Allport, from Ballybrood, in the county of Limerick.[1] The rock, he says, "contains small patches of red and green serpentine scattered through it." "In one of the largest patches there are several grains of olivine, and an examination in polarized light shows that it was originally a nest of olivine which has been almost completely altered to serpentine."

Dr. Teall,[2] in referring to Mr. Allport's description, remarks that "this is an extremely important observation, because it is the only one yet made of the occurrence of anything like an olivine nodule in any British basalt".

In 1894, in describing a basalt from Calton Hill, Derbyshire, I mentioned the presence of olivine in small groups or nests of crystals[3]; and in 1907 I stated that I had found olivine in small nests of bottle-green colours.[4] The largest nest of olivine and augite then found by me measured only $2{\cdot}7 \times 2{\cdot}2$ mm. under the microscope.

Trial holes have recently been made in Calton Hill, Derbyshire, which is a volcanic vent of Carboniferous age, and a level has been

[1] "On the Microscopic Structure and Composition of British Carboniferous Dolerites": Q.J.G.S., 1874, vol. xxx, p. 552.
[2] *British Petrography*, 1888, p. 246.
[3] Q.J.G.S., 1894, vol. l, p. 621.
[4] Q.J.G.S., 1907, vol. lxiii, p. 252.

driven through the agglomerate on the northern slope of the hill into the basalt. It has, therefore, been possible for me not only to examine the relationship between the agglomerate and basalt, but also numerous blocks of the basalt, many of which contain olivine nodules. The largest nodule I have found is 2¼ inches in length, and from one trial hole I obtained forty-nine nodules in less than an hour.

In the level, which is about 50 feet in length, the agglomerate is at first in horizontal beds. Further into the hill the beds dip to the south. The dip increases until it becomes nearly vertical at the junction between the agglomerate and basalt. The agglomerate varies in coarseness and consists of basalt lapilli either in a limestone paste or in a volcanic detritus. The former kind is very similar to the agglomerate of Ember Lane, near Bonsall. The agglomerate of Calton Hill contains lumps of limestone, which are often more or less marmorized, pieces of basalt and inclusions of silica and calcite, which are several inches in length. Two thin slices of these inclusions were examined. They consist of crystalline calcite and of quartz grains, in the form of a mosaic, and are probably a secondary aggregate of quartz and calcite.

The Basalt of Calton Hill

consists of olivine and big augite phenocrysts in a groundmass of small felspar laths, augite grains, and prisms, and magnetite or ilmenite. The felspars and augite prisms often show a well-marked flow-structure. The constituents of the rock are generally in a fresh condition. The olivine, which is sometimes altered to serpentine along the cracks, occurs in phenocrysts and in groups of phenocrysts, and in irregularly shaped grains. The augite appears as large phenocrysts, often showing hour-glass structure, and sometimes containing portions of the groundmass, and in small prisms and grains. Both olivine and augite are found together in small nests or groups of crystals. The felspars sometimes occur in two generations and often exhibit a flow-structure.

The Nodules.

The distribution of the nodules is general throughout the basalt of Calton Hill. In a hand-specimen they are easily distinguished and appear as a crystalline aggregate of bottle-green and yellow olivine with dark augite in the fine-grained and nearly black basalt. Some of the nodules are in a very fresh state; in others the cementing material between the grains has been dissolved away and the small grains may easily be separated by the finger. The nodules consist mainly of olivine, but contain a fair proportion of augite, and in some cases a small quantity of picotite. These minerals occur in irregularly shaped grains without any crystalline boundary, except in very few instances, especially near the outside of a nodule. The grains are not deformed crystals, but have hindered one another's development as far as crystalline boundary is concerned. Fourteen thin slices from the nodules were examined.

The olivine in the nodules is often traversed by cracks containing serpentine, and in some cases calcite and oxide of iron. Otherwise this mineral is in an unaltered condition. It sometimes contains

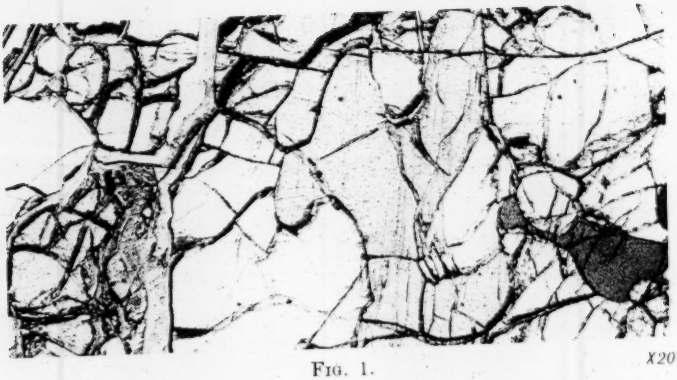

FIG. 1. X20

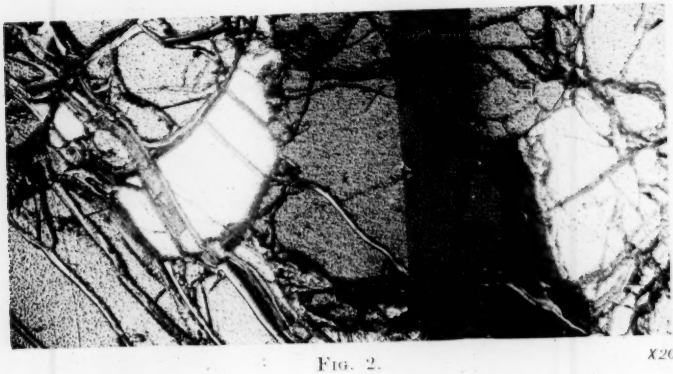

FIG. 2. X20

FIG. 3. X20

H.A.B., Photomicro. Benrose, C[illegible]

Olivine Nodules in Basalt.
Calton Hill, Derbyshire.

inclusions which give it a very rough appearance under the microscope. Some of the olivine grains are twinned many times. One twin in thin slice 1479 consists of twelve portions, another consists of five parts. It is almost impossible to distinguish the boundaries of the twins in ordinary light, but in polarized light the whole or part of a grain is divided into broad plates which differ little from each other in colour, the sides of which, corresponding to the trace of the twinning planes are often, but not always, parallel to one another. The angles of extinction of adjacent portions differ only by a few degrees and extinction in all cases is either parallel or nearly parallel to the trace of the twinning planes.

The pyroxene in the nodules is monoclinic and can only be referred to augite. In the absence of crystallographic outlines the only method of distinguishing between the orthorhombic and monoclinic pyroxenes is to measure the angles of extinction with regard to the cleavages and to observe the optic figures in convergent light. In the thin slices examined there is no certain trace of enstatite or orthorhombic pyroxene. On the other hand, the whole of the evidence points to the presence of monoclinic pyroxene or augite. Two types of cases occur in which the crystalline grain is traversed by parallel cleavage lines. In the one extinction takes place parallel to the traces of cleavage and in convergent light shows an optic axis just outside the field of view. These are augite grains parallel to (100). In the other the angle of extinction varies from a few degrees up to an angle of 45° and denotes augite from the prism zone. Few cases are present of pyroxene showing an almost rectangular cleavage, but in all these there is an optic axis nearly in the centre of the field, which proves that the mineral is augite and not enstatite.

Picotite is present in the nodules only to a slight extent. It is of a yellowish-brown colour in ordinary light and becomes extinct under crossed nicols.

The presence of olivine and of augite in small groups from almost microscopic dimensions up to a length of more than two inches in the Calton Hill basalt is in favour of the nodules being segregations from the magma and not enclosures of older rock.

EXPLANATION OF PLATES I AND II.

[The figures were photographed by the author from the microscope, under polarized light with crossed nicols.]

Plate I.

Fig. 1. Thin slice (1464), magnified twenty diameters, showing olivine grains in a nodule. The olivine is traversed by cracks containing serpentine and minute pieces of black iron ore.

Fig. 2. Thin slice (1464), magnified twenty diameters, showing olivine grains in a nodule. The grain of olivine near the centre of the figure is twinned; one portion of the twin extinguishes parallel to the trace of the twinning plane and the other at an angle of 4° with it.

Fig. 3. Thin slice (1479), magnified twenty diameters, showing part of a large grain of olivine in a nodule. The olivine is traversed by cracks and shows multiple twinning. The twinning planes are not always parallel, and the extinction angle of each portion of the twin is either parallel or nearly parallel to the trace of the twinning plane.

PLATE II.

FIG. 1. Thin slice (1459), magnified fifteen diameters. The two large dark grains with parallel cleavage lines are augite. That on the left extinguishes parallel to the cleavage and shows in convergent light an optic axis just outside the field of view, and is, therefore, parallel to (100). The lighter one at the left-hand bottom portion of the figure extinguishes at an angle of 5° with the cleavage cracks and shows only a slight trace of an axial figure. To the left and the right are several olivine grains. At the right-hand top corner is a small portion of the basalt in which the nodule occurs.

FIG. 2. Thin slice (1459), magnified twenty diameters, showing the junction between a nodule and the basalt in which it occurs. In the nodule, in the upper part of the figure, olivine and augite are seen, and in the lower part the flow-structure of the felspar microlites in the basalt.

FIG. 3. Thin slice (76), magnified fifteen diameters. Basalt containing phenocrysts of augite and olivine in a groundmass of felspar microlites of magnetite and glass. The big crystal of augite, to the left, contains inclusions from the groundmass zonally arranged. On the right is a small phenocryst of olivine.

II.—NOTES ON NEW OR IMPERFECTLY KNOWN CHALK POLYZOA.

By R. M. BRYDONE, F.G.S.

(PLATE III.)

(*Continued from Vol. VI, p. 400.*)

MEMBRANIPORA HUMILIATA, nov. Pl. III, Figs. 1–3.

Zoarium always adherent.

Zoœcia generally elongated, but very variable in shape and dimensions; length of area ·68 to ·48 mm., breadth of area ·36 to ·2 mm.; no front wall, side walls very low, with a further depression at the head of the zoœcium, and furnished all round with slender buttresses, which are much more easily distinguished in the upper part of the zoœcium, owing to their greater size and projection there, than in the lower part.

Oœcia semi-elliptical in outline, relatively very small, very frequently present, very brittle and especially so when associated with avicularia, so that zoœcia with typical arrangement of perfect oœcium succeeded by avicularium are exceedingly rare.

Avicularia accessory, small oval rings lying at the head of the zoœcium and normally symmetrically above the oœcium when present, but sometimes beside it.

The species is easily distinguished by the abnormal shallowness of the zoœcia, which makes specimens look to the naked eye like much-worn remains of other species, and causes such inequalities in the underlying surface as the smaller tubercles of *Echinocorys*, which would be out of sight at the bottom of zoœcia of normal depth, to show up most prominently.

Fairly common at Trimingham.

MEMBRANIPORA ANTERIDES, nov. Pl. III, Figs. 4–6.

Zoarium always adherent.

Zoœcia pyriform with subtriangular area and considerable extent of front wall below it; length of area ·32–·36 mm., width of area ·2–·24 mm.; side walls supported by buttresses; at the head of the

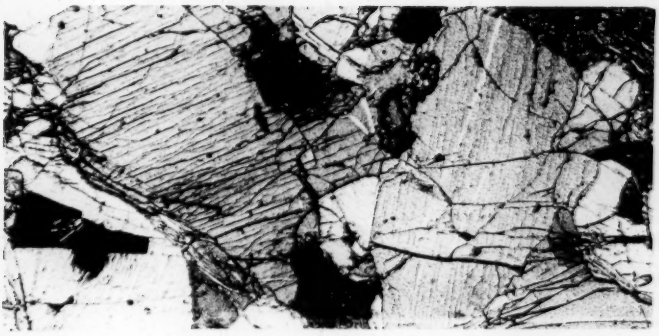

Fig. 1. X15

Fig. 2. X20

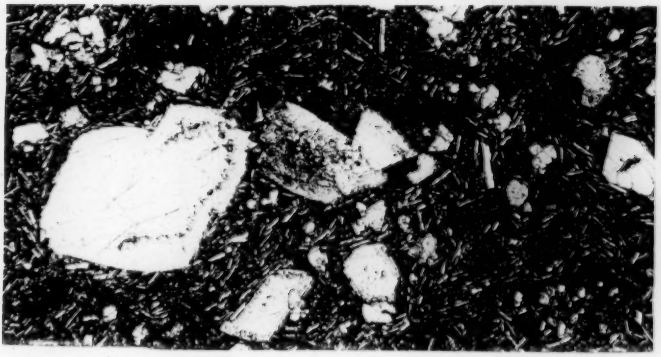

Fig. 3. X15

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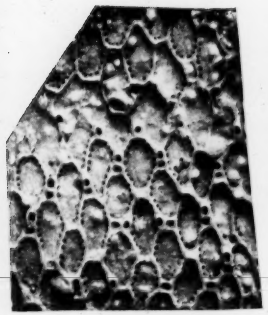
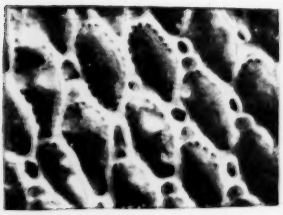
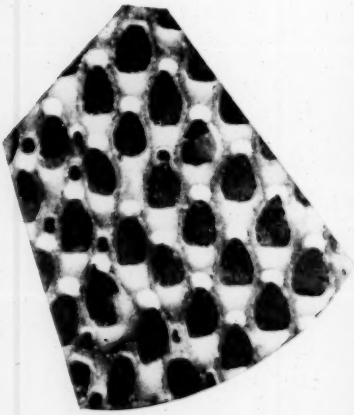
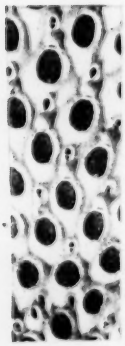
Olivine Nodules in Basalt.

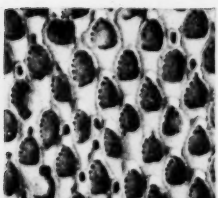
Calton Hill, Derbyshire.

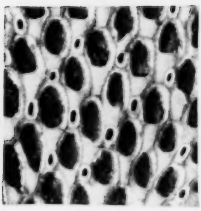


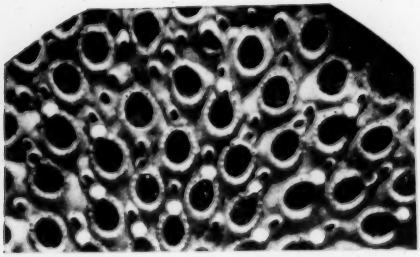












R. M. Brydone photo.

Chalk Polyzoa (Bryozoa).

zoœcium there is generally in the central line a buttress distinctly bigger than the others, with a considerable interval on either side of it. The zoœcia are much deeper than those of *M. humiliata*, though still on the shallow side, and their edges are wrinkled, but so faintly that it is only clearly discernible with the larger magnification.

Oœcia more globose than those of *M. humiliata*.

Avicularia very similar to those of *M. humiliata*.

The typical arrangement of the oœcium and avicularium is the same as in *M. humiliata*, but while they never lie side by side, in one instance two avicularia have been found to one zoœcium, which arrangement is at present unknown in *M. humiliata*.

Not uncommon at Trimingham.

The system of buttressed walls which this species shares with *M. humiliata* marks them off clearly from all other Cretaceous *Membraniporæ*, but the typical arrangement of avicularium above oœcium links them, probably only superficially, with *M. Griffithi* and *M. Trimminghamensis*.

Membranipora Trimminghamensis, mihi. Pl. III, Figs. 7 and 8.

I take this opportunity of supplementing from photographs of the type-specimen the figure given with the original description. Further study has shown that the two upper pairs of granules are perforate and the oœcia are shaped like an inverted water-bottle, the expanded lip curving round and practically hiding the uppermost pair of granules, which are smaller than the succeeding pair. Length of area ·36 mm., width ·28 mm.

In describing this species (the specific name of which should have been spelt *Triminghamensis*) and *M. Griffithi* I omitted to discuss *Cellepora trifaria*, Hag.,[1] which shows a similar arrangement of oœcium and avicularium, relying perhaps overmuch on the facts that Marsson did not refind such a form at Rugen, and did not find the species recognizable in Hagenow's collection. The figure appears to be taken from a worn specimen, which might equally well be *M. Griffithi*, *M. Triminghamensis*, or some other species. The description only adds the feature of possessing large earshaped avicularia; and these separate it as well from *M. Triminghamensis*, which has no large avicularia, as from *M. Griffithi*, which has symmetrical large avicularia, while the ear is decidedly unsymmetrical. *Cellepora trifaria* cannot therefore be treated as a valid anticipation of either of the other species.

EXPLANATION OF PLATE III.

Fig. 1. *Membranipora humiliata*. × 20.
,, 2. Ditto, another specimen showing perfect oœcium associated with avicularium in typical arrangement. × 20.
,, 3. Ditto. × 40.
,, 4. *Membranipora anteridea*. × 20.
,, 5. Ditto. × 40.
,, 6. Ditto, another specimen with the buttresses showing dark against white chalk. × 20.
,, 7. *Membranipora Triminghamensis*, type-specimen. × 20.
,, 8. Ditto, type-specimen, lighted to show bar across perfect avicularia. × 20.

[1] Geinitz, *Grundriss der Versteinerungskunde*, p. 617, pl. xxiii *b*, fig. 10.

III.—Notes on the Æolian Deposits on the Coast at Étel, Morbihan. Part I.

By Rev. R. Ashington Bullen, B.A. Lond., F.L.S., F.G.S., etc.

(PLATE IV.)

§ 1. Étel: Introduction.
§ 2. Raised Beach recently exposed.
§ 3. The Granulitic Rock.
§ 4. Traces of Post-Neolithic Submergence.
§ 5. General remarks on the direction of the Rivière d'Étel, near the sea.
§ 6. The present Terrace Beach of pea-sized gravel.
§ 7. The four Terraces on the seaward side, and their flora.
§ 8. The Æolian Transport of Sand, etc., to form the Dunes.
§ 9. Marine species contributing materials for dune formation, especially Mollusca.
§ 10. Analysis of the Dune Sand.
§ 11. Need of further work on Sand-dunes.

§ 1. Étel is situated on the west of the Megalithic district of which Carnac is the centre. It stands about 2 kilometres from the sea on the Rivière d'Étel. This so-called river is really an arm of the sea, which drains the extensive estuarine basin to the north-east, which is, in its way, almost another Morbihan (Little Sea) similar to the well-known one farther east. The tide rushes into the latter at a rate of from 7 to 11 knots per hour, at neap and spring tides respectively, and its ingress into and egress from the Rivière d'Étel cannot be much less. M. P. Le Strat, who has been much at sea in different parts of the world, considered that the incoming tide was rushing in at a rate of 7 or 8 knots an hour under the bridge of Lorrois, where the river narrows, when we passed it on October 11, 1909. The channel of the Rivière d'Étel is thus kept permanently open, and ships of from 50 to 150 tons are engaged in the tunny fishery and smaller boats in the sardine trade. Messrs. Peneau have a sardine-curing establishment at La Magoire, just opposite, across the river (Diagram, Text-fig. 1, p. 7).

An expert naval officer kindly furnishes the following information :—

(1) The rate the tide enters the Rivière d'Étel is 4 knots on the flood and it leaves at 5 on the ebb at spring tides. The latter, under special circumstances, might be more, but the amount the sailing directions give is the usual rate.

(2) The depth in the navigable channel is from 3½ to 8 fathoms.

(3) The depth on the bar is about 1 foot at lowest water. The rise of water above this is, springs 16 or 17 feet, neaps 12 or 13 feet.

(4) The bar has been known to dry as much as 8 feet at low-water. The wind also causes it to shift.

(5) A hurricane blows from 80 to 100 miles an hour. The pressure at the latter speed is 49·2 lb. per square foot.

§ 2. Quite recently the road to the beach at the point marked (×) in the map, has been widened, and the clear perpendicular section reveals a Raised Beach, the base of which is about 15 feet above high-water mark, which probably, at the recent spring tide early in October (7th) last, reached its maximum, as it was aided by strong gales. The section of the Raised Beach now exposed shows a thickness of 2 ft. 3 in. to 2 ft. 6 in. It consists of well-rounded pebbles of opaque-milky, transparent, or fibrous quartz, stained a deep red,

together with what is probably Lydian Stone: but these rocks must form the subject of a second part of this paper. This raised beach

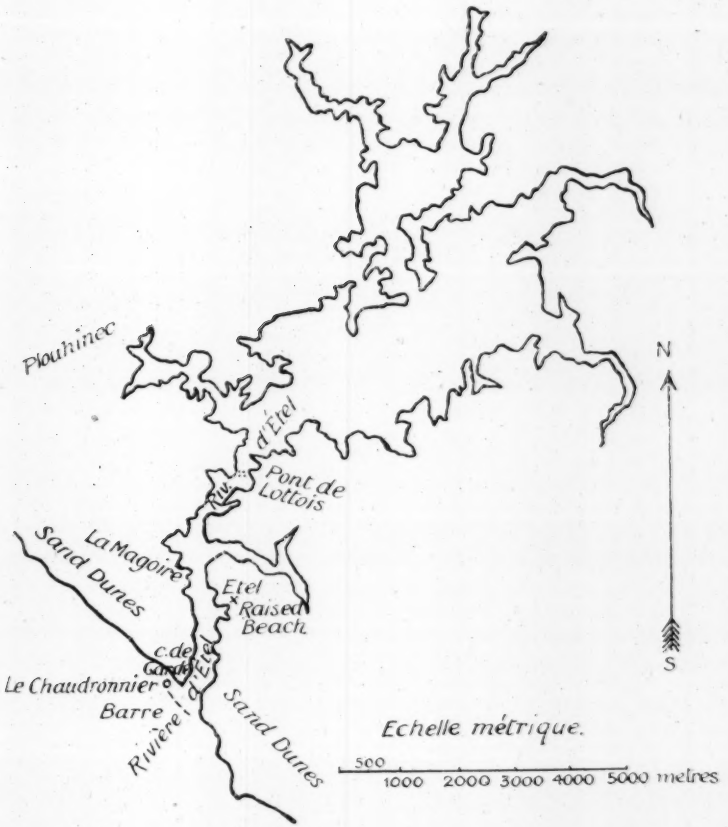


FIG. 1. Diagram of Étel, estuarine area, rivers omitted. [N.B. for Lottois read Lorrois.]

is overlain by from 3½ to 4 feet of very dark brown, vegetable, peaty-looking mould, irregularly and sparsely scattered in the lower half of which are similar raised-beach pebbles (Text-fig. 2). Unfortunately, the rest of the Raised Beach on the other side of the road has been quarried away, but the section that remains above the solid granulite contains a few scattered pebbles. No local granulitic pebbles occur in the Raised Beach, although some angular granulitic fragments do occur in the 'overburden' of mould. After careful examination no marine shells, fragmentary or otherwise, were to be seen in the Raised Beach. The absence of local stone in the Raised Beach itself is noteworthy. The raised beaches of this region must have been

formerly very extensive, judging by the vast number of derived pebbles of the same materials to be found on the present beach at Étel and elsewhere, and on the exposed point near the *barre* on the left bank of the river.

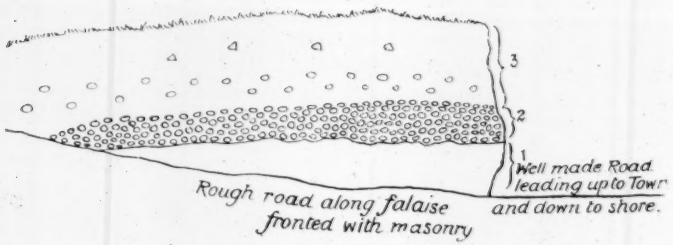


Fig. 2. Raised beach quarried away on east side of road.

1. Granulite: about 2 ft. 6 in. in deepest exposure.
2. Raised beach: resting directly on the solid rock, 2 ft. 3 in. to 2 ft. 6 in.
3. 'Head': with occasional subangular granulite in its upper part and scattered pebbles in its lower, 3 ft. 6 in. to 4 feet, mould dark-brown peaty colour.

§ 3. The underlying rock of the place is 'granulite' (using the term in its French sense). "La granulite forme trois trainées principales, toutes dirigées à 104° et par suites parallèles entre elles. La première (trainée de Locronan), très étendue sur les feuilles voisines, ne forme que le coin N.E. de la feuille; la seconde (trainée de Rosporden) s'étend de Trévoux à Inzinzac; la troisième (trainée de Port-Louis) s'étend des Îles Glenan à Etel . . . la granulite de la 3ième trainée est plus franche (de la structure feuilletée) plus massive et à plus gros grains, dans les falaises des Glenans, de Ploemeur, de Port-Louis et de Gavre; sphène, mica noir très épigenisé en mica blanc, mica blanc, oligoclase, orthose, microcline, quartz."[1] Grains of mica are plentiful in the present beach-sand and in the blown-sand of the dunes, thus showing that the blown-sand is derived from the present beach.

Between the Îles Glenan, 60 kilometres to the west of Étel and the mainland, the trawl brings up large pebbles of granite and porphyry, which belong to the raised beaches of the region. But the rolled pebbles that are found in the *grèves* of Plouhinec (5 miles from Étel westward) and behind the sand-dunes seem to have been derived from a different district from the pebbles of the Glenan area.

According to the French survey the district between the Blavet and Étel Rivers bears traces of a vast and ancient estuary.[2]

§ 4. Large masses of peat, some 1½ to 2 feet across, and about 3 inches thick, one rolled into a rounded peat 'boulder', occurred on the sea face of the coast, near the 'Chaudronnier' or 'Pierre d'Étel' (see Diagram 3), and these, derived from some submarine area, coupled

[1] Note explicative, Sheet 88, Carte Géologique détaillée de Bretagne. Note explicative, Sheet 89, Carte Géol. det. "Cette granulite . . . continue de Port-Louis à la Rivière d'Auray." Mr. F. H. Butler points out that the French 'granulite' is equivalent to the fine-grained muscovite-biotite granite of English petrologists (*vide* Harker, *Petrology for Students*).

[2] Ibid.

with the 'Dolmen-sous-marin' overgrown with seaweed, near Carnac-Plage and others elsewhere, point to a movement of subsidence, in or after Neolithic times, and posterior to the Raised Beach epoch, similar to that of the British Isles.[1] (See Plate IV, Fig. 1.)

§ 5. The course of the Rivière d'Étel from Étel to the sea is almost due north to south, and is undoubtedly due to the underlying granulite, which crops out at the Lighthouse point with a slight orientation to the south-east, and a dip to the east. We were exceptionally favoured with a violent gale on October 8, 1909, so that the action of the prevailing south-west wind could be well observed. The sea broke with unceasing fury on the granulite mass, one large rock of which standing close in-shore, the Pierre d'Étel, well named the 'Chaudronnier', on which a beacon is built, was in a constant smother of water and at times invisible. There is a ladder up the beacon, but the chance of any swimmer reaching it would be very small. The lighthouse is built on the solid land farther in from the sea.

On this side of the river (the right), for 12 kilometres, stretch dunes of blown-sand, used by the French Government for testing the heaviest artillery, occasionally with fatal results to indiscreet explorers. Last year (1908) an ancient building, rather primitive, was unearthed about a kilometre south of La Magoire. The Curé of Plouhinec considers that this is an old chapel of Ste. Brigitte, the church of a small settlement of poor fishermen, burnt down during some raid. It was surrounded by burials, but so far I have been unable to learn any more about its age. The sand-dune which covered it being cleared away, much charred wood was found and some interments. There are no modern buildings near it; the sand has now entire possession of the place (Diagram, Text-fig. 3, p. 10).

Judging by the size of some of the lichens, these dunes have not greatly increased inland for several years, any increase probably taking place along the sea-edge of the area. The absence of pebbles on this series of dunes is remarkable, and also the fineness of the sand.

The natural effect of the south-west wind would be to bend the mouth of the river to the south-east, but the strong scour of the incoming and outgoing tide is such that the contour of the banks is not altered nor is there anything at the mouth in the nature of a 'fleet', and the *barre* across the entrance can be sailed over at all suitable times of tide.

§ 6. Passing now to the consideration of the east or left bank of the Rivière d'Étel, near its mouth, along the edge fretted by the waves (which is a somewhat coarse quartz sand), we find that above the tide-mark landward, for a distance of some 200 yards in breadth, the beach material is a quartz gravel of well-worn oval or round pebbles, mostly varying from the size of a pea to a small French bean, out of which small gravel everything has been riddled, seemingly by the action of the prevalent south-west wind.

There are occasional lines of large white gravel, resembling the stones of the Raised Beach (×) before described. (Text-fig. 1, p. 7.)

[1] See Prestwich, *Geology*, vol. xi, p. 525; Q.J.G.S., 1892, vol. xlviii, p. 304. Also "Les Megalithes submergés des Côtes de Vendée", par Dr. Marcel Baudouin: *L'Homme Préhistorique*, 1er Mai, 1905, No. v, pp. 130–48.

The small pea-sized gravel underlying these lines of stones predominates. It is noteworthy that the same sort of gravel occurs at Constantine Island, Cornwall, as a Raised Beach [1] underneath the blown-sand, and on which the prehistoric, probably Neolithic, oblong 'potter's house' (discovered by Mr. Harold Hellyar, of Harlyn) used to exist before it was ruthlessly destroyed in 1902.

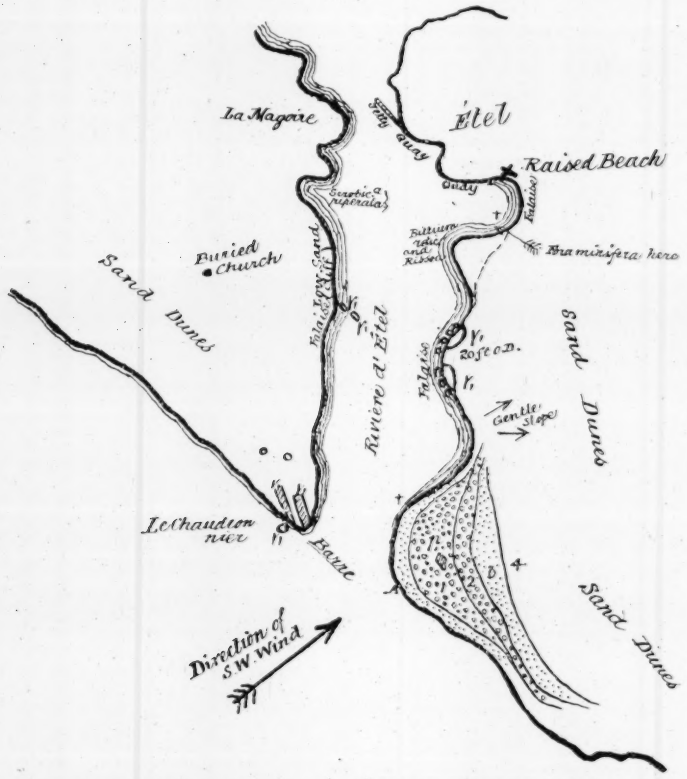


Fig. 3. Diagram of the Rivière d'Étel below Étel and La Magoire.

1, 2, 3, 4, successive terraces. *p*, pond. Y_1, granulite outcrops. † †, marine mollusca. A, steep face of present beach.

Sepia officinalis, *Bittium reticulatum*, *M. edulis* (Young), *Cy. europæa*, *Cardium edule*, various Tapes, *Donax vittatus*: very abundant on left bank from † to †.

The sea-front material, now acted on by the waves, consists of a coarse sea-sand which appears to be driven in from seaward. The small pea-gravel appears to be much older than this coarse sea-sand, and the question naturally arises whether the former is not rather to be correlated with the before-mentioned Raised Beach (×), close to the town of Étel, especially as it stands at nearly the same level above

[1] Prestwich, Q.J.G.S., vol. xlviii, p. 282.

high-water mark. At any rate, one thing seems certain, viz., that the pea-sized gravel is not being added to by wind or wave at the present time, nor for a long time past. At the same time it is well to mention that the pebbles of the Raised Beach (×) stand directly on the bare granulite and are not underlain by the pea-gravel, though this may only be because so much of the foreshore of the Raised Beach has been destroyed by erosion.

§ 7. The pea-gravel and blown-sand rise in terraces, commencing above the coarse sand of the sea-front, in the various stages of consolidation which are roughly indicated by the accompanying section (Diagram, Text-fig. 4).

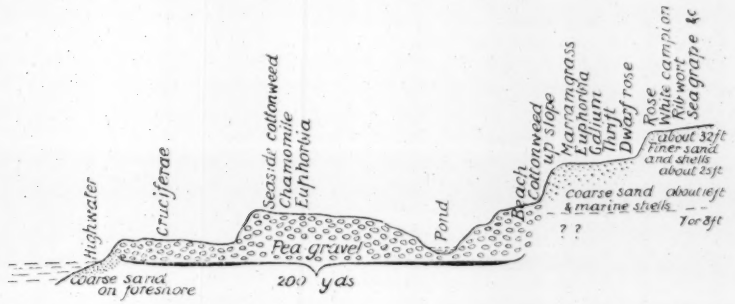


Fig. 4. Diagram of terraces at mouth of river, left bank. (For relative positions see Diagram, Text-fig. 3, p. 10.)

The plant which bears the brunt of the storm nearest the sea-front on the first terrace about 7 or 8 feet above high-water mark, is a Crucifer, *Cakile maritima*, Scopoli. I counted thirty-seven clumps of this hardy plant. The next terrace, about 9 feet higher, is occupied by seaside cotton weed, *Diotis maritima*, Coss.; chamomile, *Matricaria inodora*, var. *maritima*, L.; sea-spurge, *Euphorbia paralias*, L.; a smaller species of spurge, E. *peplis*, L. They occurred in the order named as to precedence, though they were, of course, mixed together in the rear.

Behind these there occurs a small depression, at a much lower level, containing brackish water, probably at sea-level, and about 150 yards from the sea-margin. The salt water would be able to filter in through the intervening sand and the depression would also act as a soak for fresh water from the dunes. The shells that occurred in the saline pond were *Natica catena* and *Cardium tuberculatum* principally.

Behind the second terrace and up its slope seaside cotton weed was in great abundance, the marram grass, *Ammophila arenaria*, Link,[1] only commencing to appear on this third terrace, at a height of 25 feet or so above high-water mark. With the marram grass were associated the above-named spurges, and also bedstraw, *Galium arenarium*, Loisel; *Ranunculus ficaria*, L. (lesser celandine); thrift, *Armeria maritima*, Willdenow; and a dwarf rose, from 1 to 4 inches high, *Rosa pimpinellifolia*, Loisel.

[1] Coste, *Flore de la France*, iii, p. 562.

Farther inland comes a fourth terrace, about 50 yards north, on which occur large patches of *Rosa pimpinellifolia*, and also equally vigorous sea-grape, *Ephedra distachya*, L., whose sweet, slightly acidulated berries in rank abundance coloured the dunes a brilliant coral-red. Also in smaller quantity occurred sea campion, *Silene maritima*, Withering; a dwarf ribwort, *Plantago maritima*, L.; and, of course, marram grass. What strikes one is the fact that the marram grass only occurs where the sand grains become small and therefore plays a subordinate part in 'dune formation' on this coast. Indeed, the mosses and lichens seem of almost equal importance with the marram grass in covering and consolidating the finer sand. This remark also applies to the sand-dunes of Perranzabuloe and the Trevose peninsula. Along this terrace at the foot there is a well-defined beach of large quartz pebbles.

On the opposite side, the right bank, of the Rivière d'Étel, near the lighthouse, where the sand is fine-grained, marram grass comes well forward to the advance-guard of yellow-horned poppy, *Glaucium flavum*, Crantz (*luteum*, L.), not more than 30 yards from the sea-front; the latter plant also occurs in abundance with sea-holly, *Eryngium maritimum*, L., on the second terrace of the left bank above described, where the plants are rather more sheltered (see Diagram 3).

Many other plants also occur in the groups on the third and fourth terraces; it is not, however, the purpose of this article to be botanically exhaustive, but only to trace the principal plant-agents in helping to consolidate the sand-dunes. Those who wish to do so, will find the subject more fully treated in a paper by M. Eugène Simon.[1]

§ 8. On the sand-dunes occur a number of marine shells, many of them of considerable size and weight, e.g. *Nassa reticulata* and *Purpura lapillus*. They are found at heights of quite 30 feet above the highest tides. It is difficult to account for their occurrence. They are not used for human food; these dunes are singularly void of bird-life; the dunes are not cultivated by man, nor, so far as one can see, have the shells been accidentally dropped in the places where they are found by farmers wheeling them across the dunes with seaweed, and they occur in places where fishermen's nets are not dried. Also they occur in places where there is no reason to carry them, for there are easier ways to the cultivated fields at the back of the sand-dunes. Nor, on the other hand, does wind seem to be the direct transporting agent. In the violent storm of October 8 last I placed single valves of such large shells as *Cardium tuberculatum* on their convex side; the south-west gale simply turned them over and propelled them no farther. Yet *C. tuberculatum*, either as whole shells or fragments, occurs plentifully at all levels up to the heights named above.

Probably the wind acts, in a sense, indirectly in moving molluscan and other remains up the sand-slopes to the higher levels. The movement of the sand-grains inland is facilitated by the threshing action of stranded and moored seaweed, which, detaching the particles from the beach, causes them to be borne along in the direction of the

[1] "Notes sur les associations végétales maritimes": Niort. Bull. Soc. Bot. des deux Sèvres, 1902 (1903), xiv, pp. 242–50.

wind. Quite large bundles of seaweed were observed rolling along the surface of the sand, and probably here we have an explanation of the fertility of the dunes in their own peculiar flora, and also of the presence of even large sea-shells on them, which shells, entangled in the masses of dryish seaweed would be easily transported inland and rolled upward. This would be especially easy on the sand-dunes of the left bank, between the falaises (or sea cliffs, granulite capped with sand) and the pea-gravel beach, since the slope here down to the Rivière d'Etel is a very gentle one, for it does not rise in the bluff terraces that characterize the sea-front.

§ 9. The materials that are triturated on the seashore or by the moving sand to yield the calcic portion of the sand-dunes are derived from marine Mammalia, Pisces, Mollusca, Echinodermata, Crustacea, and other flotsam and jetsam stranded on the shore. In October last two skulls of freshly dead *Delphinus delphis*,[1] and a complete *Phocæna communis*,[1] whole fishes of the genus tunny, the 'germon' *Thynnus alalonga*, were there in August last, and their bones in abundance in October. Crabs of the genus *Portunus* were also in evidence, and of echinoderms *Strongylocentrotus lividus* and an embryonic heart-urchin were not uncommon.

Mr. R. Holland has kindly examined the sea-sand submitted to him for foraminifera, and reports as follows: "A prolonged search has resulted in the discovery of a few miliolinæ only (probably *M. seminulum*, Linné). They are very poor specimens, and I have not come across a trace of any other genus of foraminifera. Besides the numerous molluscan shells I have noticed a few worm-tubes, one or two ostracod valves, a few echinoderm spines, and some very doubtful fragments of bryozoa."

The marine molluscan fauna of Étel resembles that of Weymouth in most respects. I give a list of species that I was able to collect. Those most abundant belonged to the Sepiidæ, Cardiidæ, Donacidæ, Mactridæ, Cypræidæ, Cerithiidæ, Veneridæ, and Mytilidæ. *Ostrea edulis*, *Pecten maximus*, and *Venus verrucosa* were almost entirely represented by old valves, much bored by *Cliona perforans*, such material being easily broken by the pounding action of the waves. These old shells are brought in from seaward. This is an important point when we consider the sand-dunes as encroaching on the sea, since the sea is adding to the land from its own resources.

CEPHALOPODA.

Sepia officinalis, L.
S. rupellaria, D'Orb.

GASTEROPODA.

Patella vulgata, L.
Helcion pellucidum (L.).
Fissurella reticulata, Don.
Calliostoma zizyphinus, L.
C. exasperata, Penn.
Gibbula umbilicata, Mont.
G. tumida, Mont.
G. cineraria, L.
Phasianella pullus (L.).
Scala communis, Lam.
S. clathratula (Adams).
Natica catena (Da C.).
N. alderi, Forbes.
Littorina littorea (L.).
L. littoralis, L.
L. rudis, Maton.
Rissoa costata, Adams.
R. costulata, Alder.
R. parva, Da C.

[1] Perhaps these should be excluded as they were probably killed by fishermen, but they show the possibility of such material floating ashore.

Rissoa violacea, Desm.
R. striata, Adams.
R. membranacea, var. *cabiosa*, Mont.
R. proxima, Alder.
R. rufilabris, Mont.
Alvania lactea, Mich.
Barleeia rubra, Mont.
Bittium reticulatum (Da C.).
Turritella communis, Risso.
Chenopus pes-pelecani, L.
Cypræa europæa, Mont.
Ocinebra erinacea (L.).
Purpura lapillus (L.).
Nassa reticulata (L.).
N. incrassata (Strom.).
N. pygmæa, Lam.
Buccinum undatum, L.
Bela turricula, Mont.
Mangilia (*Hadropleura*) *septangularis*, Mont.
M. costata (Don.).
Thesbia nana (Lovén).
Actæon tornatilis, L.
Dentalium dentalis, L.
Acera bullata, Müll.

PELECYPODA.

Anomia ephippium, L.
Arca lactea, L.
Mytilus edulis, L.
M. adriatica, Lam.
Ostrea edulis, L.
Pecten maximus, L.
P. varius, L.
P. pusio, L.
P. operularis, L.
Lima hians, Gmel.
Diplodonta rotundata, Mont.
Tellina incarnata, L.
T. balthica, L.
T. tenuis, Da C.
T. donacina, L.
Gastrana fragilis (L.).
Donax vittatus (Da C.).
Spisula solida, var. *elliptica*, Brown.
Mactra stultorum, L.
Venus fasciata (Da C.).
V. verrucosa, L.
V. gallina, L.
V. chione, L.
Irus irus, L.
Tapes decussata, L.
T. aureus, Gmel.
T. pullastra, L.
T. virgineus, L.
Cardium tuberculatum, L.
C. norvegicum, Speng.
C. edule, L.
Psammobia vespertina, Ch.
P. ferroensis, Ch.
Solen siliqua, L.
S. ensis, L.
Pholas candida, L.
Pandora inæquivalvis, L.

Brackish-water shells, brought down from the upper reaches, or living near Étel, where fresh water runs into the river, and mud accumulates.

Lutraria oblonga, Ch.
Scrobicularia piperata (Gmel.).

Helicella barbara (L.), so common on our own sand-dunes in Cornwall, Portland, etc., was not observed at Étel. It occurred, with other xerophilous molluscs, at Auray, sunning itself on the hottest day of August last in the hottest places in bright sunshine on walls. On the other hand, *Helix pisana*, Müll., in countless myriads, provides its quota of material, organic and inorganic, to the general mass of the dunes. It is accompanied by *Pomatias elegans*, Müll., and *Helicella itala*, L., in considerable numbers.

§ 10. The rough proportion of calcic material in the sand of the dunes is about one part in three by weight. I carefully dried the sand from the dunes, and then treated it with hydrochloric acid; it was afterwards carefully washed eight times to remove the acid, and the residue after being thoroughly dried was again weighed, with the above result. Out of 875 gr. (2 oz.) Avoir., so treated, the residual quartz, mica, etc., weighed 582·625 gr., showing a loss by dissolution of 292·375 gr. of calcic material. *Bittium reticulatum* is so abundant as in places to colour the dune sand brown. The colouring matter was dissolved with the shell material.

§ 11. Much work remains to be done at our own sand-dunes, as

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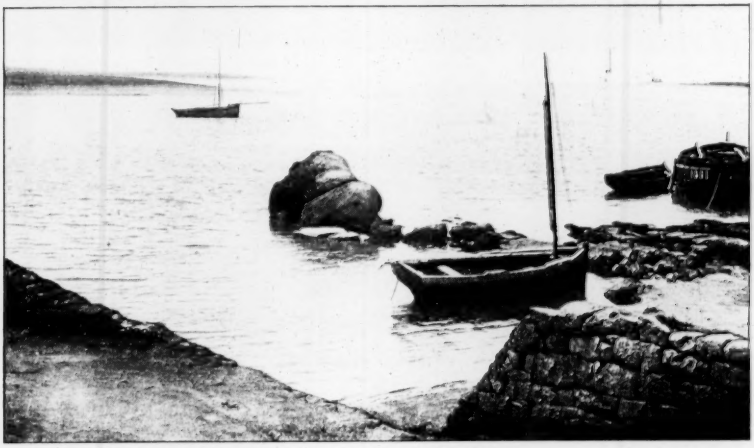

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Fig. 1. Submerged Dolmen near Carnac Plage.
.. 2. Granulite rocks at Cap de Garde.

witness the hitherto unsuspected occurrence, November, 1908, of an old lake-bottom at Perranzabuloe,[1] 200 feet O.D. Though much of this chara-marl has been carted away by agriculturists as fertilizing agent, enough remains to yield a most curious limnic molluscan fauna, scarcely to be paralleled according to Mr. A. Santer Kennard, F.G.S., among the existing British freshwater fauna of the present day.

I have to thank Mr. W. H. Griffin and my wife for botanical help; and my friend Dr. Henry Woodward, F.R.S., for this opportunity of placing my notes for revision, if needed, before abler and more competent minds who have given thought to this fascinating subject.

EXPLANATION OF PLATE IV.

FIG. 1. Dolmen-sous-marin near Carnac Plage.

,, 2. Granulite rocks at Cap de Garde. The Chaudronnier, or Pierre d'Étel, surmounted by a beacon. The Lighthouse stands somewhat inland (see ,, next view).

,, 3. Étel, view southwards from close to the Raised Beach. The Lighthouse and storm signal station are to the right of the Chaudronnier.

IV.—Pleochroic Halos.

By F. P. Mennell, F.G.S.

(PLATE V.)

THE subject of 'pleochroic halos' has become endowed with peculiar interest since Professor Joly suggested that they are due to the radio-activity of the inclusions round which they occur.[2] On looking into such petrographical literature as I possess, it appears that very few precise observations have been made regarding these halos, and it has occurred to me, therefore, that some of my own notes on the subject may be of general interest.

Minerals causing or showing Halos.—The usual type of halo, as seen in rock sections, is a dark spot of roughly circular outline surrounding a small centrally situated enclosure in another mineral. The enclosing mineral may or may not itself be pleochroic, though it usually is so, or would appear so in thicker slices. The following is a list of minerals which have, to the writer's knowledge, been found to show halos, though it must be stated that in some of them the phenomenon is very rare: biotite, augite, hornblende, muscovite, chlorite, tourmaline, cordierite, staurolite, and andalusite. As to the minerals producing the halos, identification is not always easy, owing to their minute size. The following have come under the writer's notice: zircon, sphene, apatite, orthite (allanite), and epidote. It is needless to point out that all these latter minerals (except, perhaps, epidote) are known to be, comparatively speaking, strongly radio-active. As far as the rocks are concerned, halos are far more common in those of igneous origin than in the other classes, and are especially noticeable in the plutonic types, particularly the granites. It may be noted that even zircon, round which halos are most frequently met with, may occur enclosed in such a susceptible mineral as biotite without the slightest trace of

[1] Proc. Malac. Soc., vol. viii, pp. 247 and 374.
[2] Phil. Mag., 1907, p. 381.

any halo being seen. However, a halo round zircon is certainly the normal state of affairs, and the same may be said of orthite. It is curious to notice that large crystals of these minerals may fail to give rise to halos, though these last may be conspicuous round the smaller crystals in the same slice. Round apatite and epidote halos are only occasionally seen, and are usually faint, while round sphene they are extremely rare.

Shape of Halos.—It is evident that, if three dimensions are considered, halos are usually spherical, and thus give circular sections, except in cases where the enclosed crystal is distinctly elongated and of sufficient size for the difference of length and breadth to be appreciable. In the case of large irregular grains or granular aggregates the halo may be quite irregular in shape, but extends to a uniform distance from each part of the margin of the substance which it surrounds.

Size. — A feature revealed by measurement is the remarkable uniformity in size of the halos. The distance to which they extend from the edge of the enclosed crystal appears practically uniform in nearly all cases. Of course there are numerous instances where halos apparently smaller than usual are observed, owing to the dark sphere not having been cut centrally, but in these no nucleus can be seen. There do, however, appear to be some small halos which cannot be thus accounted for. On the other hand the alteration of minerals like orthite tends to produce stains which spread principally along cracks or cleavage planes, and must be carefully distinguished from real halos.

The following are some approximate measurements, made by means of an eyepiece micrometer, of the breadths of fairly well-marked halos seen round various distinctly visible minerals in a variety of rocks:—

Round Zircon.

	mm.
In biotite of granite, Haytor, Dartmoor	·03–·04
In biotite of granite, Rubislaw, Aberdeen	·03
In biotite of granite, Cowra, New South Wales	·035
In biotite of granite, Gadara, New South Wales	·02
In biotite of granite, Cape Town	·035
In biotite of granite, Matopos, Rhodesia	·03–·04
In biotite of granulite, Rhodes' Drift, Rhodesia	·04
In hornblende of granite, Weinheim, Baden [1]	·03
In hornblende of granite, Bulawayo, Rhodesia [1]	·03
In hornblende of diorite, Jahonda, Rhodesia	·035
In augite of granulite, Amazon Mine, Rhodesia [1]	·03
In chlorite of granite, Mountsorrel, Leicester	·03
In chlorite of granite, Matopos, Rhodesia	·03
In chlorite of granite, Cowra, New South Wales	·04
In tourmaline of granophyre, Cornwall	·03–·035
In tourmaline of granite, Cape Town	·03
In cordierite of granulite, Bodenmais, Bavaria	·045
In cordierite of granite, Cape Town	·035
In 'pinite' of granite, Cape Town	·035

Round Apatite.

In biotite of granite, Cape Town	·03
In biotite of diorite, Hillside, Rhodesia [1]	·03
In biotite of granulite, Amazon Mine, Rhodesia	·02
In biotite of granulite, Rhodes' Dritt, Rhodesia	·03

[1] Nature of enclosed mineral somewhat doubtful.

	mm.
Round Sphene.	
In biotite of granulite, Amazon Mine, Rhodesia	·02
In hornblende of granite, Umguza River, Rhodesia	·03
In augite of syenite, Hillside, Rhodesia [1]	·03
Round Orthite (Allanite).	
In biotite of granite, Matopos, Rhodesia	·03–·04
In biotite of granite, Zimbabwe, Rhodesia	·035
In hornblende of granite, near Blanket Mine, Rhodesia	·03
In hornblende of 'tonalite', Adamello, Tyrol [1]	·035
In hornblende of diorite, Jahonda, Rhodesia	·04
Round Epidote.	
In chlorite of granite, Matopos, Rhodesia	·03
In biotite of granite, Gadara, New South Wales	·025

The above measurements are necessarily somewhat rough, as it is difficult to keep an eye on the halo and the micrometer scale at the same time. However, the general result is to emphasize the uniformity of size and the fact that there does not seem to be any definite relation between such variations as are noticed and the minerals concerned.

Halos and Radio-activity.—Professor Joly has pointed out that the penetration of the *a* rays emitted by radium compounds is about ·04 mm. in the case of aluminium, and having regard to the slightly greater density of the minerals examined, the results are in close agreement with the theory that the halos are due to the alteration of the surrounding minerals by those rays.[2] Some of the smaller halos were indistinct, and it seems possible that in several cases where rather low values were obtained, the radio-active substance was present merely as an inclusion in the interior of the mineral to which the halo appeared due. This is the more probable as such minerals as apatite and sphene cannot be radio-active in virtue of their normal constituents, or even their usual impurities.[3] Epidote, too, may owe its occasional activity to minute inclusions of orthite. As bearing on this point, may be noted a granite from the Zimbabwe Ruins in Rhodesia, which contains apparently primary epidote enclosed in biotite. The epidote in turn encloses irregular patches of orthite, and wherever the latter approaches within ·035 mm. of the edge of the epidote, the biotite within that limit shows the usual darkening. It is noteworthy that zircon may always be expected to contain traces of thorium, and orthite invariably contains that element in appreciable amounts, and probably uranium as well in some cases. From a petrological point of view it seems as if thorium should be a far more potent cause of radio-activity in the earth's crust than uranium and radium. We know of no widely distributed uranium-bearing rock-former, while zircon is found everywhere, and orthite is far from rare in many regions.[4] Over 15 per cent. of my slides of granites contain it. Monazite, always rich in thorium, is also

[1] Nature of enclosed mineral somewhat doubtful.

[2] *Radio-activity and Geology*, p. 68.

[3] See, however, Strutt, Proc. Roy. Soc. A., 1908, p. 275.

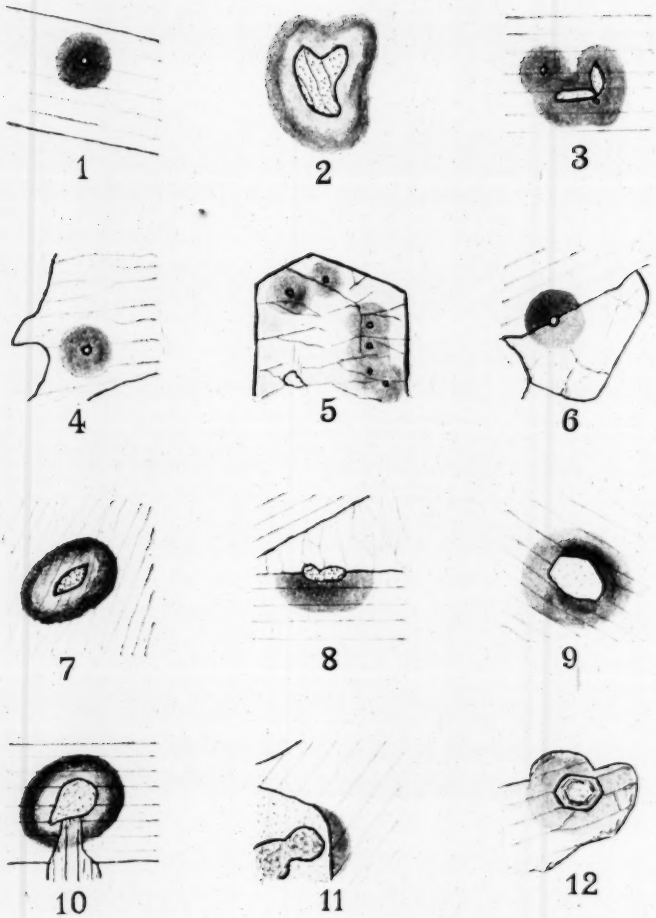
[4] See, for instance, Geol. Mag., 1903, Dec. IV, Vol. X, p. 347, and *Geology of South Rhodesia*, pp. 29–32.

found in many rocks. It is as yet scarcely possible to judge how the recently discovered radio-activity of potassium affects the question, though the abundance of that element renders the fact of obvious importance.

Various Features.—When the halos are fairly intense, they usually have quite well-defined boundaries, much more so than one is inclined to think before making a series of observations on the point. Where they are clearly perceptible in the direction of minimum absorption they show no increase of diameter when placed in the position of maximum absorption. Sometimes, however, a halo appears in the latter position, whereas none was perceptible in the direction at right angles to it. This is especially the case with such faint halos as those sometimes seen round epidote or sphene, or those in cordierite. The more intense halos are usually uniform in tint from inside to outside, or slightly lighter towards the outer edge. Irregularities in distribution are, however, fairly frequent, and the halos are sometimes dark and light in uneven patches. In certain cases, too—always, apparently, round rather large inclusions—the halos may have a rim darker than the interior. Thus, in the granite to the north of Kahlele's Kraal, in the Matopo Hills, Rhodesia, there are well-marked halos round good-sized orthite crystals enclosed in biotite. These halos are usually very sharply defined on the outside, and have the margins distinctly darker than the parts nearer the orthite. A similar feature may be noticed round some of the zircons in a biotite granulite from the neighbourhood of Rhodes' Drift on the Limpopo River, Rhodesia. It is also well seen round the larger zircons in the well-known cordierite granulite of the Bodenmais, Bavaria.

The halos round the minute zircons in the tourmaline of the Cornish granophyre (quartz-porphyry) in the list given above are interesting as extremely good examples of a phenomenon distinctly rare in tourmaline, though noticed long ago by Michel Lévy.[1] That this mineral does not readily lend itself to the formation of pleochroic halos is obvious from the evidence of such rocks as the Cape Town granite. My slides of specimens from near the contact show several instances of small zircons at the junction of biotite flakes and tourmaline crystals, and whereas the biotite shows a semicircle of intense pleochroism, the halos are incomplete, owing to the tourmaline being entirely unaffected. The same fact was noted at several junctions of biotite and cordierite, though in one case a good example of a composite halo, half in biotite and half in cordierite, was observed. Several fairly distinct halos were also seen round zircons, entirely enclosed in tourmaline, and we may perhaps infer that in these particular cases the enclosures were more strongly radio-active than usual. It is noticeable that where the cordierite of this rock has been altered into the so-called 'pinite' pseudomorphs, the halos are much more intense than in the fresh cordierite itself. Halos in hornblende are rather rare, though this is perhaps due partly to the much greater scarcity of inclusions than in biotite,

[1] See *Minéraux des Roches*, p. 288.



Pleochroic Halos around inclusions in various minerals.

which seems always to have crystallized by preference on a nucleus of previously formed accessory minerals. In contrast to tourmaline and hornblende, it is remarkable to find halos well shown in such minerals as augite and muscovite, which are not normally pleochroic. It is also an interesting point that halos never seem to occur in minerals capable of causing them, a fact which appears entirely in accord with the radio-active theory of their origin. Thus there are none round the inclusions of zircon in the large orthite crystals of the Jibuyi River granite in North-Western Rhodesia, nor does the epidote of the same rock show any where it encloses orthite crystals, a feature which may also be noticed in numerous other Rhodesian granites, e.g. those of the Matopos, Kalomo, and the Zimbabwe Ruins.

I must mention, in conclusion, my obligations to Mr. G. W. Card, of Sydney, who sent me the New South Wales rocks mentioned above, and to Mr. A. E. V. Zealley, who kindly brought to my notice the Cornish granophyre, also referred to.

EXPLANATION OF PLATE V.

FIG.

1. Ordinary type of circular halo round zircon in biotite, breadth about ·035 mm. In granite of Matopo Hills, Rhodesia.
2. Halo round irregular zircon inclusion in cordierite, rim of halo darker than interior. In granulite of Bodenmais, Bavaria.
3. Halos round group of zircon crystals in biotite. In granite of Sea Point, Capetown.
4. Halo round zircon in hornblende, breadth about ·035 mm. In quartz diorite of Jahonda, Rhodesia.
5. Halos round zircon in tourmaline. In Cornish granophyre, exact locality unknown; slide lent by A. E. V. Zealley, A.R.C.S.
6. Halo partly in biotite and partly in cordierite, round zircon. In granite (near contact) of Sea Point, Cape Town.
7. Halo, with dark rim, round zircon in biotite. In biotite granulite, near Rhodes' Drift, Limpopo River, Rhodesia.
8. Semicircular halo in biotite, not extending into adjacent tourmaline. In granite, Sea Point, Cape Town.
9. Halo, unevenly tinted, round apatite in biotite. In granulite, near Rhodes' Drift, Rhodesia.
10. Halo, with dark rim, round orthite (allanite) in biotite. In granite, north of Kahlele's Kraal, Matopo Hills, Rhodesia.
11. Halo in biotite, near inclusion of orthite in epidote. In granite, near Zimbabwe Ruins, Rhodesia.
12. Halo, about ·04 mm. in breadth, round orthite in hornblende. In quartz diorite of Jahonda, Rhodesia.

(The magnification is about 100 diameters.)

V.—The Ore-bearing Pegmatites of Carrock Fell, and the Genetic Significance of Tungsten-ores.

By A. M. Finlayson, M.Sc., Assoc. Otago School of Mines, F.G.S., Assoc. Inst. M.M.

Introduction.—The wolfram veins in the Grainsgill greisen, near Carrock Fell, are an example of ore-bearing pegmatites, a vein-type uncommon in the British Isles, and one, moreover, the study of which is of much interest in its relation to ore-genesis. The veins have long been known, and intermittently exploited for tungsten-ore, but their economic prospects are not bright. Of previous workers, Mr. Alfred

Harker has described the greisen which carries the veins,[1] while the various mineral occurrences have been recorded by Mr. J. G. Goodchild[2] and others.

The Country Rock.—The veins occur in Brandy Gill, a small stream running into the Caldew from the western slopes of Carrock Fell. The country rock is a detached intrusion of greisen, related to the Skiddaw granite, and of post-Silurian age. Mr. Harker has pointed out that it is an acid modification of this granite, containing 77·26 per cent. of silica, as against 75·223 per cent. in the normal biotite granite of Skiddaw.[3] In the ore-bearing portion, felspar becomes very subordinate or disappears altogether, white mica replaces biotite, and quartz phenocrysts compose the bulk of the rock. Tourmaline occurs occasionally, but topaz and cassiterite are absent. In classing this rock as a greisen, Mr. Harker has shown that its features are due, not in this case to the action of pneumatolytic processes on a normal granite, but to intense mechanical pressure on the magma, resulting from the post-Silurian crust-movements, at the time of its intrusion.[4]

The Grainsgill greisen has many features in common with the *beresite* of the Urals, which contains the gold-quartz veins of Berezovsk,[5] and with the *alaskite* of Mr. J. E. Spurr.[6] The latter rock, an acid modification of normal granitic or syenitic intrusions, occurs as dykes at Goldfield [Nevada], in the Yukon gold-belt of Alaska, and elsewhere. These various types are probably closely allied in nature and origin.

The Veins.—The wolfram veins in the greisen consist of some half-dozen chief members running north and south across Brandy Gill, and outcropping on the steep slopes on either side of the valley. They vary in width from a few inches to 3 or more feet, and consist essentially of coarse quartz, with flakes of pale mica and crystals of pale or bluish-green apatite. The vein-walls, though fairly well-defined, are not marked by clay selvages or slickensides, the veins being, in the phraseology of the American miner, "frozen to the country." Another notable feature is the marked absence of pneumatolytic effects, such as the development of schorl-rock, topaz, or fluorspar in the vein-zones.

The most easterly vein, which is also the largest, carries wolframite, with a subordinate quantity of associated scheelite, distributed in irregular bunches through the vein. The quartz is conspicuously banded and comby, and small vughs are common. Some arsenopyrite is generally present, scattered through the veins in small crystals. Molybdenite also occurs, in its usual habit, but this mineral appears to be chiefly developed in a single vein towards the west, which is

[1] Quart. Journ. Geol. Soc., 1895, vol. li, pp. 139 et seqq.

[2] "Contributions towards a list of the minerals in Cumberland and Westmorland": Trans. Cumb. and West. Assoc., 1881–2, vii, p. 101; 1882–3, viii, p. 189; 1883–4, ix, p. 175.

[3] Harker, loc. cit. sup.

[4] Id. ib., p. 143.

[5] Von Arzruni, *Zeits. deutsch. geol. Gesell.*, 1885, xxxvii, p. 873, and Posepny, *Guide du VII Congrès Géol. Internat.*, 1897, v, p. 42.

[6] "Geology of the Yukon Gold Belt, Alaska": 18th Ann. Rep. U.S. Geol. Surv., 1896–7, pt. iii, p. 230.

practically free from tungsten-ores. The small size of the veins and the sparing quantity and irregular distribution of the ores give no promise of ore-bodies of any consequence. As secondary products, there appear small quantities of the yellow tungstite (tungstic ochre) and molybdite (molybdic ochre). Native bismuth and bismuthinite are also recorded from this district, as well as the mineral grünlingite, a variety of tetradymite having the formula $Bi_4 S_3 Te$.[1]

The Vein-minerals and their Relations.—The quartz of the veins is glassy and crystalline, in coarse granules, and containing scattered patches of white mica. The apatite occurs in long striated prisms, terminated by the base or pyramids, and its colour varies from pale yellow or lemon-yellow to green. An analysis of the mineral gave the following result, showing it to be a fluor-apatite :—

Ca O	= 54·11	$Al_2 O_3$	= 0·87
$P_2 O_5$	= 40·56	$Fe_2 O_3$	= 1·05
F	= 2·98	Mg O	= 0·24
C	= 0·66		
		Total	100·47

The vein-mica is commonly gilbertite, of a yellow or greenish tinge, frequently associated in flakes with the apatite. In Cornwall, where it was first described, this species often occurs as an alteration-product of orthoclase,[2] and in some districts it is pseudomorphous after both scheelite and apatite. Here, however, it appears to be of primary origin. An analysis of the mineral revealed the presence of 0·92 per cent. of fluorine. This is of interest, in view of the widespread occurrence of fluorine in potash-micas, which has lately been emphasized by Mr. J. E. Spurr.[3] Thus the gilbertite from Ehrenfriedersdorf contains up to 1·04 per cent. of fluorine.[4] The very small quantity of fluorine or other 'mineralizers' in the Cumberland veins is in harmony with the absence of pneumatolytic products.

The wolframite occurs in coarse bunches embedded in quartz. The prism-faces are longitudinally striated, and fairly complete crystals are not uncommon, the usual form being a combination of prisms and ortho-pinacoid, terminated by ortho-domes and pyramids. The composition of the mineral, as determined by analysis, is as follows :—

$W O_3$	= 76·24
Fe O	= 16·39
Mn O	= 6·05
Ca O	= 1·05
Mg O	= 0·11
Total	99·84

The scheelite is white to brownish-yellow in colour, and occurs, when crystallized, in tetragonal bi-pyramids. Under the microscope it is colourless, and when suitably cut shows its prismatic cleavages, *p* (111) and *e* (101), intersecting. The individual crystals, as distinguished under crossed nicols, are coarse and closely interlocked.

[1] Muthmann & Schroeder, *Zeits. Kryst. u. Min.*, 1898, xxix, p. 144.
[2] F. H. Butler, *Min. Mag.*, vii, p. 79.
[3] "Geology and Mining Industry of Tonopah": Prof. Paper No. 42, U.S. Geol. Surv., 1905, pp. 231–3.
[4] Frenzel, *Jahrb. Min.*, 1873, p. 794.

The mineral has been analysed by Traube, with the following result[1]:—

WO_3	= 79·97
MoO_3	= 0·35
CaO	= 19·27
Total	99·59

The presence of molybdenum is worthy of note, this constituent having been shown by Traube to be almost universally present in scheelite.

The relations of the minerals may be more clearly studied under the microscope. The opaque wolframite encloses quartz in thin strings along its cleavage-planes, as well as in granular aggregates. Separated grains of quartz are often seen to extinguish simultaneously, and at other times the two minerals simulate a graphic intergrowth. Again, quartz may occur as a thin selvage to the wolfram. The intimate association of these two constituents clearly shows close relation in order of deposition. While frequently there has been practically simultaneous deposition, on the whole the wolframite appears to have preceded the quartz. Crystals of arsenopyrite are almost invariably deposited on wolfram or formed in microscopic cavities of the ore. This sulphide is probably very largely of metasomatic origin.

The scheelite, in contrast to the wolframite, is remarkably free both from arsenopyrite and from quartz. This would be expected from the fact that the arsenopyrite is a metasomatic product after wolframite, and the wolframite and quartz were deposited about the same time, while the scheelite is clearly of later date. This mineral frequently fills cracks in the wolframite, and while the border-line between the two minerals is generally sharp, the scheelite is invariably deposited or grown on the older mineral. Occasionally the line of junction is irregular, and shows a gradual progression of the scheelite by replacement of the wolframite. The observed relations leave little doubt that the scheelite is metasomatic, although the processes are not in every case obvious under the microscope. The order of deposition of the minerals was apparently (1) wolframite and quartz, (2) arsenopyrite and scheelite.

It is to be noted that there are two lime-bearing minerals in these veins, namely, scheelite and apatite. The latter was perhaps the earliest of all in order of deposition, and it is not clear to what extent, if at all, the scheelite has derived its base from this constituent. In any case, this occurrence of lime is of interest, since it has been pointed out that in the magmatic differentiation of the greisen from the biotite granite of Skiddaw there has been a reduction of the alkalis and alkaline earths by 50 per cent.[2] The lime in these two vein-minerals may then be taken to represent a portion of the surplus bases rejected by the greisen during its differentiation and crystallization, the lime being brought up at a later stage in the last phase of the magmatic processes, i.e. in the formation of the pegmatite-veins.

Tungsten-ores and Metasomatism.—The formation of tungsten-ores

[1] *Jahrb. Min.*, Beil. Bd., 1890, vii, p. 232.
[2] Harker, loc. cit. sup., p. 142.

is very frequently due to metasomatic replacement, and this may take place in one of two directions. There may be a replacement of the acid radicle by tungstic acid; or there may be a replacement of the base by lime, or by iron and manganese oxides. The former process has taken place, for example, in the scheelite deposits of Trumbull, Connecticut,[1] and in the scheelite-veins of Otago, New Zealand.[2] In both these cases, tungstic acid has combined by replacement with lime-bearing minerals in the vein-zone. Another important example is the wolfram-ore of the Black Hills, South Dakota.[3] The second process is observed where scheelite is metasomatic after wolframite, as in the present instance; and likewise where the reverse change has occurred. Thus, in the deposits at Trumbull, Connecticut, wolframite occurs pseudomorphous after scheelite. The latter change, i.e. from scheelite to wolframite, appears to be much the commoner.

Fissure-veins at Grainsgill.—There occur, associated with the Grainsgill pegmatites, typical lead-quartz veins in fissures. An example is to be seen within a few yards of the most westerly pegmatite-vein, and contained also in the greisen. It is bounded by sharply defined walls with clay selvages. The vein-filling is of brecciated, or banded and cavernous quartz, and the ore consists of small bunches of well-crystallized galena, with a little chalcopyrite. This vein has clearly been deposited in a fissure formed in the rock long subsequent to its consolidation, the fissure being, like all those which carry the lead-zinc and copper veins of the Lake District, of post-Carboniferous age. We have here, then, two distinct vein-types, which show a striking difference, both in origin and in age.

In this connexion, it is worthy of note that the lead-veins of the Lake District have yielded two minerals allied to those in the pegmatites, namely, wulfenite from Caldbeck Fell[4] and stolzite from Force Crag.[5] There has apparently been a reaction, at considerable depth, between the older tungsten and molybdenum ores and the younger lead-ores, which points to a broad genetic connexion between them.

Genetic Relations of the Grainsgill Pegmatites.—The modern views on the nature and origin of pegmatites have been recently summarized by J. B. Hastings,[6] who concludes that their essential feature is their dependence on aqueo-igneous intrusion, as applied to the influence of water in conjunction with heat in causing the liquidity of granitic magmas. In different cases it may be difficult to determine to what extent igneous intrusion on the one hand, and magmatic waters on the other, have been predominant, and it is impossible to postulate exclusively either aqueous or igneous agency, since there has clearly been a combination of both factors. G. H. Williams, in discussing the origin of the Maryland pegmatites,[7] concludes that they are of

[1] W. H. Hobbs, 22nd Ann. Rep. U.S. Geol. Surv., 1900–1, pt. ii, p. 13.
[2] A. M. Finlayson, "The Scheelite of Otago": Trans. N.Z. Inst., 1907, xl, p. 117.
[3] J. D. Irving, Trans. Amer. Inst. Min. Eng., 1902, xxxi, p. 683.
[4] J. G. Goodchild, Geol. Mag., N.S., 1875, Dec. V, Vol. II, p. 565.
[5] Greg & Lettsom, *Mineralogy of Great Britain*, London, 1858, p. 411.
[6] Bull. No. 21, Amer. Inst. Min. Eng., May, 1908, p. 319.
[7] 15th Ann. Rep. U.S. Geol. Surv., 1893–4, p. 678.

two types—segregation pegmatites and intrusive pegmatites. The view that pegmatites grade into normal quartz-veins has been maintained in different districts by various writers, as, for instance, Crosby & Fuller,[1] J. F. Kemp,[2] A. H. Brooks,[3] Joseph Barrell,[4] and A. C. Spencer.[5] R. Beck concludes that pegmatites are products of crystallization from superheated waters, which remained, after the separation of the chief constituents of the magma, as a concentrated solution containing the rarer metallic elements.[6] He is thus in agreement with Brögger, Arrhenius, Vogt, and Grubenmann, all of whom support the intimate relation between pegmatites and ore-veins. Hastings expresses similar views with respect to the pegmatites of the Eastern United States,[7] which he regards as true dykes, except where excess of water and of mineralizers have produced, first, pneumatolytic tin- and apatite-veins, and finally veins containing gold, silver, or galena.

The most pronounced advocate of the connexion between pegmatites and normal quartz-veins, however, is J. E. Spurr, who has advanced a theory of progressive derivation of gold-quartz veins from granitic magmas by siliceous magmatic differentiation.[8] While this hypothesis may be locally applicable, there are, in many districts, difficulties in the way of its acceptance, owing to the absence of transitions from one vein-type to another. To take a single instance known to the writer, the gold-quartz veins of the west coast of New Zealand,[9] while related to the tectonic movements and granitic intrusions of the Alpine region, show no relation whatever with the abundant pegmatites and barren quartz-veins of the granites themselves. Again, in the Grainsgill district under consideration we have, on the one hand, ore-bearing pegmatites representing the super-acid phase of segregation and differentiation of the magma; and, on the other hand, lead-quartz veins in fissures, showing no (structural) similarity to the pegmatites. They have clearly been deposited from circulating waters at a later date. The occurrence in the lead-veins, however, of the minerals stolzite and wulfenite, serves to link the two types together to a certain extent, and to indicate that the ores have probably been derived from a common source.

Geological Occurrence of Tungsten-ores.—The range of occurrence of tungsten-ores is very remarkable, and gives important evidence on the question of relations between the different vein-types. The facts of occurrence, with examples, are given below :—

1. *Pyrogenetic Minerals.*—Tungsten-ores occur as original pyrogenetic compounds in granitic and allied rocks, chiefly as small percentages of tungstic oxide, often with tin oxide and molybdic oxide, in tantalates

[1] *Technology Quarterly*, 1896, ix, p. 326.
[2] Bull. Geol. Soc. Amer., 1898, x, p. 361.
[3] 20th Ann. Rep. U.S. Geol. Surv., 1898–9, pt. vii, p. 425.
[4] 22nd Ann. Rep. U.S. Geol. Surv., 1900–1, p. 511.
[5] Prof. Paper No. 25, U.S. Geol. Surv., 1904, p. 41.
[6] Rep. Brit. Ass., Trans. of Sections, 1905, p. 400.
[7] Amer. Inst. Min. Eng., 1908, Bull. xxi, p. 319.
[8] Prof. Paper No. 55, U.S. Geol. Surv., 1905, p. 129, and *Economic Geology*, ii, No. 8, p. 781.
[9] A. M. Finlayson, Trans. N.Z. Inst., 1908, xli, p. 85.

and niobates. Scheelite is also recorded from granite at Chesterfield, Mass., with albite and tourmaline.[1] The scheelite occurring with piedmontite in a rhyolite at South Mountain, Penn.,[2] may also be pyrogenetic, while the segregations or secretions of wolframite in granite in the Whetstone Mountains, Cochise Co., Arizona, may be regarded as pyrogenetic.[3]

2. *Pegmatites.*—From these examples, it is a short step to the tungsten-bearing pegmatites, of which there are several types. In the first place, tungsten-ore occurs in pegmatites without tourmaline, as at Grainsgill, and similarly at Torrington, New South Wales, where it is associated with bismuth, monazite, fluorspar, and beryl.[4] Secondly, there is a wolfram-tourmaline-tin phase of pegmatites, as in the granite of the Southern Black Hills, where they carry wolframite, with cassiterite, columbite, tantalite, and tourmaline.[5] Likewise, at Etta Knob and Nigger Hill in South Dakota, the pegmatites carry wolframite and cassiterite with spodumene, lithia-mica, albite, and orthoclase.[6] A third type of pegmatites carries also iron and copper sulphides, as at Sadisdorf near Altenberg, where wolframite occurs with lithia-mica, fluorspar, apatite, and chalcopyrite,[7] and in the south part of the Sierra de Cordoba, Argentina, where the veins contain wolframite, apatite, mica, molybdenite, pyrite, and chalcopyrite.[8] Similarly, in granite near Encruzilhada, Rio Grande, Brazil, wolframite occurs in a quartz-vein with muscovite, pyrite, and chalcopyrite.[9] All these three types of pegmatite-veins are closely allied, and, further, they show clear transitions to the pneumatolytic type of vein, and to the normal type of sulphide-vein.

3. *Pneumatolytic Veins.*—In this well-known type the tungsten-ores are associated with tin and tourmaline, as in Cornwall. The type is also well developed in Tasmania and Northern New South Wales, while many of the Spanish and Portuguese occurrences are of this type, as at Villa Real and Castello Branco.

4. *Contact-deposits.* — In some instances, tungsten-ore occurs in deposits of contact origin, where it is generally associated with characteristic silicate-minerals of the contact zone, and where replacement has generally been a factor in its formation. Thus the scheelite deposit of Long Hill, Trumbull, Conn.,[10] appears to be of this type. The deposits lie in a zone between crystalline limestone and hornblende-gneiss, and are associated with epidote and zoisite. Again, scheelite occurs in the magnetite-sulphide deposits of Pitkäranta, Finland, where limestones have been intruded by granite.[11] In Tasmania, wolframite, cassiterite, bismuthinite, and molybdenite occur

[1] J. P. Iddings, *Igneous Rocks*, New York, 1909, vol. i, pp. 42, 68.
[2] G. H. Williams, Amer. Journ. Sci., 1896, xlvi, p. 50.
[3] F. L. Hess, Bull. 380, U.S. Geol. Surv., 1909, p. 164.
[4] *Mining Journal*, 1905, p. 170.
[5] F. L. Hess, Bull. 380, U.S. Geol. Surv., 1909, p. 131.
[6] W. P. Blake, Trans. Amer. Inst. Min. Eng., 1885, xiii, p. 691.
[7] R. Beck, *Zeits. für prakt. Geol.*, 1907, xv, p. 40.
[8] Bodenbender, loc. cit., 1894, p. 409.
[9] H. Kilburn Scott, Trans. Inst. Min. Eng., 1903, xxv, p. 510.
[10] W. H. Hobbs, 22nd Ann. Rep. U.S. Geol. Surv., 1900–1, pt. ii, p. 13.
[11] Otto Trüstedt, *Bulletin de la commission géologique de Finlande*, 1907, iv, No. 19.

in quartz-veins with fluorspar and wollastonite, in metamorphic Silurian limestone penetrated by quartz-porphyry.[1] These and other deposits where contact metamorphism has clearly been operative, are related to the other types here considered, and their mode of formation has been merely a local accident.

5. *Normal Fissure-veins.*—Tungsten-ores are abundant in quartz-veins and allied deposits with sulphides and gold-ores. In the first place, there are many occurrences which show mineralogical transitions from the tin-tourmaline type. Examples of these are the quartz-veins in granite at New Ross, Lunenburg, N.S., where scheelite and cassiterite occur with iron and copper sulphides;[2] and in the Moose River district, Halifax, N.S., where scheelite occurs in gold-quartz veins with arsenopyrite and some tourmaline. In the New England district of New South Wales, wolframite and scheelite occur in veins with cassiterite, bismuth-ores, and molybdenite in a greisen,[3] an occurrence which should perhaps be classed as pneumatolytic. The Cook and Cape Yorke district of Queensland shows a marked association of gold-tungsten-tin ores; and in the important Herberton and Hodgkinson districts of Queensland, the wolframite is associated with molybdenite and bismuth-ores. Near Maunda, east of Nagpur, in India, wolframite occurs in a gold district, in bedded quartz-veins in mica- and tourmaline-schists.[4] At the Panasquiera mines, in the province of Beira Baixa, Portugal, wolframite is found in quartz-veins with cassiterite, specularite, pyrite, arsenopyrite, and mica.[5] Near Tirpersdorf in the Saxon Voigtland, veins in the contact-zone of a granite boss carry wolframite with molybdenite and tourmaline.[6] In the Predazzo district of the Southern Tyrol, veins associated with the post-Triassic intrusions carry scheelite, with copper-ores, fluorspar, arsenopyrite, and tourmaline.[7] Many of these occurrences are more closely related to the pneumatolytic type, but they illustrate the impossibility, owing to the transitions, of drawing sharp dividing lines between one type and another.

Turning to more normal types, these are common all over the world, and comprise some of the most valuable tungsten deposits. The ore—wolframite, hübnerite, or scheelite—occurs in a quartz gangue, with the commoner sulphides, and nearly always some gold. In Spain, the deposits of La Sorpresa, in the province of Cordoba, consist of quartz-veins carrying wolframite and scheelite in granite and in the adjoining slate.[8] In the Cagliari district of Sardinia, scheelite occurs in quartz-veins with stibnite, a sulphide which is frequently associated with this ore.[9] The tungsten-ores of Canada

[1] W. H. Twelvetrees & G. A. Waller, Tasmanian Government Geological Reports, 1901, etc.

[2] E. R. Faribault, Sum. Reps. Geol. Surv. Canada, 1908, p. 169.

[3] Bull. Imp. Inst., London, 1909, vii, No. 2.

[4] L. Leigh Fermor, Recs. Geol. Surv. India, 1908, xxxvi, p. 301.

[5] *Mineral Industry* for 1906, xv, p. 747.

[6] R. Beck, *Zeits. für prakt. Geol.*, 1907, xv, p. 37.

[7] J. Block, *Sitzungsber. der Niederrheinischen Gesellsch. für Natur- und Heilkunde zu Bonn*, 1905, p. A, 68.

[8] *Mineral Industry* for 1906, xv, p. 747.

[9] Domenico Lovisato, *Atti della Reale Academia dei Lincei*, 1907, ser. v, xvi, Rendiconti, p. 632.

have been described by T. L. Walker.[1] The normal quartz-veins are well developed in Beauce Co., Quebec,[2] in various parts of the Nova Scotian gold-belt, and in the Cariboo and Kootenay districts of British Columbia.[3] In all these occurrences the tungsten-ore is found in quartz-veins with gold or in gold districts. In the northern Black Hills of South Dakota, wolframite occurs in a zone of refractory siliceous gold-ores, formed by replacement of crystalline dolomite.[4] At Lane's mine, Monroe, Conn., quartz-veins carry wolframite, often pseudomorphous after scheelite, together with native bismuth, pyrite, galena, etc. In the Snake Range, White Pine Co.,[5] and at Osceola,[6] both in the State of Nevada, hübnerite occurs with scheelite in quartz-veins in granite. In Boulder Co., Colorado, wolframite is abundant in quartz-veins in a district of auriferous sulphide and telluride ores.[7] In Arizona, wolfram-ores occur throughout the gold-belt.[8] Important occurrences are in the Whetstone Mountains[9] and the Dragoon Mountains,[10] Cochise Co. In the latter district the ore is chiefly hübnerite. At Julcani, in Peru, wolframite occurs in gold-quartz veins in diorite.[11] In Western Australia, scheelite is found at Ravensthorpe, in the Phillips River Goldfield, at Kalgoorlie, and in other gold districts. In New South Wales, scheelite is abundant in quartz-veins in and near the granite intrusions of the Cordilleran Goldfield, notably at Hillgrove, where the veins also carry scheelite.[12] In New Zealand, scheelite is common in the gold-quartz veins of the Otago goldfield,[13] while stibnite is another common ore in that region. The Otago district is one of Palæozoic slates and schists, devoid of igneous intrusions to which the ores might be related, but the gold-tungsten zone clearly belongs to the same province as the gold-belt of Eastern Australia. In concluding this survey of the occurrence of wolfram-ores, mention should be made of the common occurrence of stolzite as a subordinate mineral in lead-veins, and, similarly, of cupro-tungstite with other copper-ores.

Conclusions.—It has been seen how tungsten may be followed through all stages of ore-deposition from the original magma, without any breaks in the sequence. It appears first in pyrogenetic minerals, and passes then through the different phases of pegmatites, which represent the end-products of the differentiated magma, and contain concentrations of the rarer metallic oxides. It next appears in the pneumatolytic veins, the first of the after-effects of the intrusion, and passes progressively from these, where it is associated with tin and

[1] "Tungsten-ores of Canada": Dept. of Mines, Ottawa, 1909.
[2] A. R. C. Selwyn, Rep. Geol. Surv. Canada, 1893, v, p. 74 *AA*.
[3] T. L. Walker, loc. cit. sup., pp. 36 et seqq.
[4] J. D. Irving, Prof. Paper No. 26, U.S. Geol. Surv., 1904, p. 169.
[5] F. B. Weeks, Bull. 340, U.S. Geol. Surv., 1908, p. 263.
[6] Fred D. Smith, Eng. and Min. Journ., 1902, lxxvi, p. 304.
[7] Waldemar Lindgren, Ec. Geol., 1907, ii, p. 453.
[8] Forbes Rickard, Eng. and Min. Journ., 1904, lxxviii, p. 263.
[9] F. L. Hess, Bull. 380, U.S. Geol. Surv., 1909, p. 164.
[10] W. P. Blake, Trans. Amer. Inst. Min. Eng., 1899, xxviii, p. 543.
[11] E. A. V. de Habich, *Geol. Centralb.*, 1907, ix, i, p. 9 (Abstr.).
[12] E. F. Pittman, *Mineral Resources of N.S.W.*, Sydney, 1901, and Bull. Imp. Inst., 1909, vii, No. 2.
[13] A. M. Finlayson, Trans. N.Z. Inst., 1907, xl, p. 110; 1908, xli, p. 64.

tourmaline, to the various types of normal fissure-veins, where it is associated with sulphides of iron, copper, and antimony, and to a lesser extent with lead. Throughout the sulphide zones it constantly accompanies gold. This association of tungsten with gold is one of the most significant facts in the occurrence of tungsten-ores. Mention should here be made of the occurrence of strings of gold in alluvial wolframite in the Ballinvalley stream, co. Wicklow, Ireland,[1] but it is possible that the gold has here been deposited on the wolfram by secondary action in the auriferous alluvium.

It follows that tungsten, which is found in such a continuous series of vein-types, must give important evidence as to the ultimate source of the metals with which it is associated, and since tungsten is universally a product of the acid and superacid phases of magma-differentiation in the first place, it seems probable that it is to these magmatic phases that we must look for the ultimate point of departure of many gold- and sulphide-ores, just as in the case of tin-ores. While this line of evidence as to the source of gold-ores—especially when taken in conjunction with the authentic occurrences of primary free gold in granitic rocks—supports in part the hypothesis of Mr. J. E. Spurr,[2] it is clear that the genesis of gold-ores and sulphides is much too complex to be thus dealt with. While magmatic differentiation has probably been the fundamental factor at work, there are many gold-ores which have probably originated during an intermediate or basic phase of differentiation.

Apart from the view of derivation of ores by progressive magmatic differentiation, which is strongly supported by the evidence here discussed, there remains the problem of the origin of the vein-solutions. The view advocated by Mr. Spurr, that the quartz gangue of normal fissure-veins represents the extreme product of siliceous magmatic differentiation, seems to be of very limited application. The views as to the origin of vein-forming solutions are still somewhat conflicting, but it is doubtful if any theory of vein-formation can be comprehensive which demands the exclusive agency of 'juvenile waters', and which fails to recognize the work of underground solutions of meteoric origin in the middle and higher zones of ore-deposition.

The work in connexion with this paper was carried out at the Imperial College of Science and Technology, London, and the writer is indebted to Professor W. W. Watts for advice and criticism.

NOTICES OF MEMOIRS.

On the Evidences of a Former Land-bridge between Northern Europe and North America.[3] By R. F. Scharff, Ph.D., M.R.I.A.

THE author enunciated the theory some years ago that North-Western Europe and North-Eastern America had been connected with one another by land within comparatively recent geological times, and

[1] Bull. Imp. Inst., 1909, vii, No. 2, p. 171.
[2] Ec. Geol., ii, No. 8, p. 781.
[3] From the Proceedings of the Royal Irish Academy, 1909, vol. xxviii, Section B.

that the reindeer had probably utilized this land-connexion in gaining access to Europe from its supposed American centre of dispersion. Further studies have led to the conviction that a second and more southerly land-connexion, joining Scotland, Iceland, and Greenland with America, must have existed in later Tertiary times. This does not materially alter the general principle of his original views; and he still adheres to the belief in a North Atlantic land-bridge between Europe and America during the lifetime of the reindeer.

In 1897 Mr. W. S. Green gave us the results of his expedition to the Rockall Bank. Surrounded by deep water on all sides, this bank is of an average depth of 100 fathoms, and lies far out in the Atlantic to the west of Scotland. Dredging on the bank yielded only such shallow-water species of molluscs and other marine invertebrates as could not have lived there under the present conditions. Moreover, as all the specimens were dead, it was concluded that the bank had only subsided to its present depth within comparatively recent times.[1] In 1900 the Danish 'Ingolf' expedition to Iceland likewise reported having met littoral molluscs near the island at considerable depths where these animals could not possibly have lived. That such cases as these are due to accidental dispersal by floating icebergs containing shells in the ice-foot or by floating seaweeds, had been suggested; but the view that the occurrence of shore forms of animal life in deep water implies a depression of the land seems to meet with more general favour, especially as no icebergs are known to stray to the Rockall Bank at present.

More recently Professor Hull lays stress on the occurrence of channels in submerged platforms bordering the British Isles, and urges that they represent the drowned river-valleys and cañons of an ancient land-surface. By means of the Admiralty charts he succeeded in tracing the course of the River Shannon for a hundred miles beyond its present mouth, right to the edge of the continental platform, while he followed the continuation of the River Erne for a distance of 80 miles from the Irish coast.[2]

In America similar researches have been conducted, chiefly by Dr. Spencer,[3] but while Professor Hull advocates an elevation of the land during the early part of the Glacial period of 7000 to 8000 feet, Dr. Spencer suggests an uplift of 12,000 to 15,000 feet. A more cautious attitude on these oceanographic problems was adopted by Mr. Hudleston. He conceded that some sort of a bridge across the Atlantic may have existed during portions of the Tertiary era; but he did not believe in an uplift beyond 2000 or 3000 feet.[4]

The subject of continental shelves has lately received renewed attention from Dr. Nansen, and is discussed by him at great length. At several places, he argues, there is weighty evidence for the supposition that the drowned river-valleys have been sculptured after the

[1] W. S. Green, "Notes on Rockall Island": Trans. Roy. Irish Acad., 1897, xxxi.
[2] E. Hull, "Submerged Terraces and River Valleys": Trans. Vict. Inst., 1897, xxx.
[3] J. W. Spencer, "Submarine Valleys": Bull. Geol. Soc. America, 1903, xiv, p. 224.
[4] W. H. Hudleston, "Eastern Margin of North Atlantic Basin": GEOL. MAG., 1899, p. 148.

formation of the continental shelves. The latter consequently have been dry land after their formation.[1]

The remarkable circumstance that the submarine fjord-valleys on the European and on the American side, and likewise the submarine ridges connecting the two continents, are situated at about the same depth makes it probable that the whole area had once been raised simultaneously, and had thus become connected by land. Dana long ago urged that the refrigeration of the climate at the close of the Tertiary era was connected with a period of high-latitude elevation,[2] and I cannot refrain from expressing my opinion, that the Glacial period was primarily due to the diversion of oceanic currents produced by changes in the distribution of land and water. With every respect for the views of those who hold different opinions, it seems to me that the peculiar phenomena connected with the Ice Age in Western Europe, and especially the apparent survival of southern species of plants and animals in Ireland through the Glacial period, are best explained by such a theory as that just stated.

It is especially the teachings of Edward Forbes and A. R. Wallace that led to the recognition of the significance of the present geographical distribution of animals and plants as an indicator of the changes which have taken place in the arrangement of land and water. They believed that many terrestrial animals and plants require a continuous land-surface for their dispersal. Yet the diversity and comparative richness of the fauna and flora of some of the oceanic islands, and the depth of water intervening between them and the mainland, had to be accounted for in some other manner. Neither Wallace nor Darwin was inclined to admit extensive geographical changes within the period of existing species. The distribution of plants and animals by 'accidental', or what Darwin called 'occasional', means of dispersal seemed to furnish them with a clue to the worldwide dissemination of certain species.

Darwin's experiments have found many imitators; and valuable observations tending to show that at any rate some of the more minute animals and plants are liable to be conveyed by occasional means of dispersal, have been made.

It would be idle to deny that the seeds of certain plants are carried to great distances by wind; that many others are undoubtedly transported by ocean currents; that some seeds are even scattered here and there by birds. My contention is, and I concur in this opinion with many eminent botanists, that only a small percentage of plants are disseminated and actually established in that manner. Most of them require for their dispersal a solid and continuous expanse of soil.

Sir Joseph Hooker evidently believed that the flora of Greenland had travelled across from Europe by a land-bridge in Pre-Glacial times. He considered the existing plants of the country as certainly older than the Glacial period; for he argued that the severity of the climate destroyed many species, while the remainder took refuge and survived in the southern parts of Greenland.[3] Professor James Geikie

[1] F. Nansen, *Norwegian North Polar Expedition*, 1904, iv, p. 192.

[2] J. D. Dana, *Manual of Geology*, 3rd ed., p. 540.

[3] J. D. Hooker, "Distribution of Arctic Plants": Trans. Linn. Soc., 1860, xxiii, pp. 252–5.

maintains that a land-connexion between Greenland, Iceland, the Faröes, and Scotland, must have existed, because the plants could only have migrated from Europe over a land surface,[1] but to him the idea of a survival of plants during the Ice Age in Greenland is inconceivable. He therefore argues that the land-bridge could only have existed in Post-Glacial times. Hence the Glacial period and its supposed adverse influence upon the flora of Northern Europe has now become the mainspring of most speculations as to the former presence or absence of a northern land-bridge.

The question of the supposed survival of plants through the Ice Age in Greenland largely depends on the problem whether or no the glaciers of that country had a vastly greater extension formerly than they have at present, and covered the whole of the land now free from ice. That the latter has never been entirely invaded by ice has been clearly demonstrated by the leader of the German Greenland Expedition, Dr. E. von Drygalski. The greater extension of ice in former times no doubt can be proved, he remarks; yet glaciers certainly never reached the cliffs and rock-pinnacles which abound on all parts of the coast-lands of Greenland.[2] No reason, therefore, can be adduced why the flora of Greenland should not have survived the Ice Age in that country, particularly as we have some grounds for the supposition that the land in the Arctic regions then stood higher than it does now.

It would be wrong to suppose that plant migration to the Faröes and Iceland has proceeded altogether from Europe. A stream has likewise advanced from the opposite direction. Thus in the Faröes we find at least seven plants unrepresented in the British Islands. These came from Greenland and Arctic America.

A small group of plants is of particular interest to Irish botanists, as being almost exclusively confined to the West of Ireland and North America. According to Messrs. Colgan & Scully,[3] the plants in Ireland which belong to this group include *Spiranthes Romanzoviana*, *Eriocaulon septangulare*, and *Naias flexilis*. All of these plants are indigenous and discontinuously distributed. An interval of more than 200 miles separates the northern and southern stations in Ireland of the rare orchid *S. Romanzoviana*. The water plants *E. septangulare* and *N. flexilis* inhabit not only some of the western Irish lakes, they occur also in Scotland.

Messrs. Colgan & Scully do not explain the presence in Ireland of these plants as being due to any such accidental transport. They believe them to have reached Europe by means of an ancient northern land-connexion. Mr. Praeger likewise comes to a similar conclusion with regard to the origin of the American plant group in Ireland. He does not favour the theory of accidental dispersal. A land surface, long since destroyed, of Pre-Glacial age, appeals to him as a more likely explanation of the presence of the American plants.[4]

The number of plants common to Europe and North America is really far greater than we imagine, though very few, as we have seen,

[1] James Geikie, *Prehistoric Europe*, 1881, p. 520.
[2] E. von Drygalski, *Grönland Expedition*, 1897, vol. i, p. 335.
[3] N. Colgan & R. W. Scully, *Cybele Hibernica*, 1898, 2nd ed., p. 71.
[4] R. Ll. Praeger, *Irish Topographical Botany*, 1901, p. 23.

are quite confined to these continents. Of those which also occur in Asia there are many, like the Orchid *Listera cordata*, which grows only in a few localities in the extreme east, that are apparently absent from the greater part of the continent. It is probable that all these have found their way from America to Europe by a direct passage. Moreover, we know from Professor Drummond's researches that of seventy species of fossil plants observed by him in the Pleistocene clays of Toronto in Canada, twenty occur at the present day both in that country and in Europe.[1] This seems to indicate that during the Pleistocene period, the great mass of the flora common to America and Europe had already found its way from the one continent to the other.

The zoological testimony in support of this view is of a more pronounced character. The interest aroused in Ireland by the discovery of the American plants has led to research in other directions. Thus, in 1895, three species of freshwater sponges were detected in various lakes at some distance from the sea on the west coast. Only one of these sponges, viz. *Tubella pennsylvanica*, has since been observed in another European locality, in Loch Baa in Scotland, but all of them are identical with American species.[2] Dr. Hanitsch identified them as *Ephydatia crateriformis*, *Heteromeyenia Ryderi*, and *Tubella pennsylvanica*.

In my more recent work on European Animals, I have incidentally dwelt on the past range of the Great Auk (*Alca impennis*) as indicating the presence of a former more continuous coastline between the British Islands, Iceland, Greenland, and Newfoundland, in all of which countries this bird was known to have been abundant.[3] Yet, after all, the best evidence in favour of a North Atlantic land-bridge is furnished by the invertebrates. Our special attention is drawn by Mr. Born to the importance of the 'Running Beetles' of the genus *Carabus*. From the fact of their being wingless and usually found under stones or clods of earth, they are not liable to be transported accidentally by any of the means usually supposed to aid animals in their dispersal. Mr. Born claims that at least two European species of *Carabus*, viz. *C. catenulatus* and *C. nemoralis*, have crossed the Atlantic by means of an ancient land-bridge. A third form—*Carabus groenlandicus Chamissonis*—seems to have originated in America, and to have travelled from there to Greenland and Lapland.[4]

Of another group of insects—the Collembola—Professor Carpenter remarks: "It is of interest to find that the presence of not a few species of these wingless insects in America, in Greenland, in the islands to the north of Europe and Asia, and on the Euro-Asiatic continent, lends support to our belief in a Pliocene or Pleistocene

[1] A. T. Drummond, "Plants common to Europe and America": *Nature*, 1904, lxx, p. 55.

[2] R. Hanitsch, "Freshwater Sponges of Ireland": *Irish Nat.*, 1895, iv, p. 126. Annandale, "Freshwater Sponges in Scotland": Journ. Linn. Soc. (Zool.), 1908, xxx.

[3] R. F. Scharff, *European Animals*, 1907, pp. 37–9.

[4] Paul Born, "Carabologische Studien": *Entomol. Wochenblatt*, 1908, xxv, pp. 8, 9.

land-connexion to the north of the Atlantic Ocean—a belief already upheld by so much evidence, both geological and zoological."[1]

Quite a number of naturalists believe that any resemblance between the European and the American fauna must have arisen, not from any direct intercourse between Europe and America, but by a migration across Asia and a Bering Strait land-connexion. The supposition of an ancient northern Pacific land-bridge presents fewer difficulties to them than the Atlantic one, and is preferred for that reason. Dr. Horváth, for example, who states that no less than 128 species of Hemiptera are common to the two continents, argues that they all must have crossed Asia in reaching the one from the other.[2] But he and those who agree with him were apparently unaware that certain freshwater species common to Europe and America are almost totally absent from Asia or Western America.

Let us take, for example, our common Perch (*Perca fluviatilis*), a variety of which also inhabits North America. It is absent not only from a large part of Asia, but also from Western North America. Certainly this looks like a case of direct migration from America to Europe.

Another example that I have had occasion to quote in my work on *European Animals* (p. 35) is the freshwater Pearl-Mussel (*Meleagrina margaritifera*). On our continent it inhabits the British Islands except Eastern England, the mountain streams of Scandinavia, and the hill-region of Central Europe except the Alps. Far to the east it reappears in a different form in the River Amur in Eastern Siberia, in the island of Sakhalin, and in Kamchatka. Another variety is met with across the Bering Strait in Alaska and in Western North America generally. The type form occurs in the Quebec province of Canada, in the Lower Saskatchewan River, and in New England. The typical freshwater Pearl-Mussel is only met with in Eastern North America and in Central and North-Western Europe. America is undoubtedly its original home. From it the mussel spread to Europe in an eastward direction, and not by way of Asia. As the fry of these mussels attach themselves to the gills of fishes, they are liable to wide dispersal within at least one river system; but fishes in this case could scarcely have aided them in reaching Europe. A land-connexion between the two continents explains their distribution certainly better than any other theory.

The most striking piece of evidence we possess in favour of a Pre-Glacial land-connexion between North-Western Europe and North-Eastern North America is the presence in the latter country of the snail *Helix hortensis*.

A western species in Europe, *Helix hortensis*, is remarkable for its extensive northern range. It occurs in Scandinavia, all over the British Islands, in the Shetlands and Faröes, and even in Iceland. It is altogether absent from Asia. Its occurrence in Southern

[1] G. H. Carpenter, "Collembola from Franz Joseph Land": Proc. R. Dublin Soc., 1900, ix. p. 276.

[2] G. Horváth, "Faunes hémiptérologiques": Ann. Hist. Nat. Mus. Hungarici, 1908, iv. pp. 4–7.

Greenland had generally been attributed to a recent human introduction; but it has been taken in several different localities, and we must, I think, look upon it as an indigenous species. During the year 1864 Professor E. S. Morse discovered the shell of this snail among ancient 'kitchen-middens' on some of the islands off the coast of Maine. This fact led him to consider that the snail had wandered along some ancient coastline from the Old World across the North Atlantic. Dr. Binney, and more recently Professor Cockerell, concurred with Professor Morse's opinion, while the Rev. Mr. Winkley even suggested that *Helix hortensis* arrived in North America before the advent of the Glacial period. With the latter theory Mr. Johnson, another conchologist, expressed his agreement; and it is to his paper that I am indebted for the above-mentioned information.[1]

All doubts as to the claim of *Helix hortensis* being an indigenous American species are now set at rest through the discovery by Dr. Dall of the shell of this snail in undoubtedly Pleistocene deposits in the State of Maine.[2] Moreover, the species is now known to inhabit a much greater area than was formerly supposed; for it has been collected in Labrador, Newfoundland, Prince Edward Island, and many other small islands where it could not possibly have been brought by man. It may, therefore, be considered as definitely established that *Helix hortensis* reached America in Pleistocene or Pliocene times without human intervention.

The discovery of *Helix hortensis* in Greenland is an important factor in favour of the land-connexion theory. That this species should have survived the Glacial period in that country need not surprise us; for several other species of land and freshwater molluscs certainly must have done so. *Planorbis arctica*, *Limnæa Vahli*, *L. Wormskioldi*, *Succinea grœnlandica*, *Vitrina angelicæ*, *Pupa Hoppii*, and *Conulus Fabricii* are almost all confined to Greenland, and no doubt originated there in Pre-Glacial times.

Of all the theories which have been advanced in explanation of the occurrence of identical species on both sides of the Atlantic Ocean, only the following three have met with wide approval:—

1. Migration from Europe across Asia and a Bering Strait land-bridge to America or vice versa.
2. Occasional transport by birds across the Atlantic Ocean.
3. Migration across a direct Atlantic land-connexion.

If we consider the zoological evidence alone, namely, the absence of *Helix hortensis* from Asia and Western America, the distribution of the Perches and the freshwater Pearl-Mussel, and that of the freshwater Sponges, the first of the three hypotheses is scarcely applicable to these instances of distribution, and does not, therefore, explain the presence of identical species on both sides of the Atlantic in a satisfactory manner.

As regards the supposed conveyance by birds of seeds and invertebrates across the same ocean, the second theory must be

[1] C. W. Johnson, "Distribution of *Helix hortensis*": *Nautilus*, 1906, xx, p. 73.
[2] W. H. Dall, "Land and Freshwater Mollusks": Harriman Alaska Exped., 1905, xiii, p. 20.

applicable to a transport in two directions, both from America to Europe as well as vice versa.

The fact that both in America and Europe the indigenous species of plants and animals identical to the two continents are largely confined to the coast region may appear at first sight in favour of the theory of introduction by birds. Almost all the American plants, and all the American freshwater sponges at any rate, occur in the vicinity of the coast. It has been argued, therefore, that, after their long flight across the ocean, birds would naturally alight on the earliest opportunity; and that it was for this reason that the plants and animals common to the two continents were so largely confined to the coastal districts. But from what has been mentioned we have no reason to infer that American birds do habitually alight on the west coast of Ireland on first reaching Europe. It seems highly probable that they cross by way of Greenland. We should, therefore, expect all species of the invertebrates and plants common to the two continents to be found in Greenland as well. This is not so. Only comparatively few of them are met with in Greenland. The theory that the resemblance in the fauna and flora of Eastern North America and Western Europe is due to the action of birds is, I think, not supported by sufficient evidence.

The third theory, that the identical species on either side of the Atlantic Ocean are the result of a direct land-connexion between Scotland, Iceland, Greenland, and Labrador, appears to me to be well founded on geological, bathymetrical, and biological evidence. No decisive testimony, however, has as yet been brought forward to show during what geological period this land-bridge was formed and how long it lasted. The assumption that such geographical conditions prevailed during early Tertiary times is very widespread. That this state continued during the Miocene period is likewise maintained by many; though Professor Dawkins and a few others do not admit the existence of the northern land-bridge in Pliocene or more recent times.[1] Sir Archibald Geikie's researches point to the production of the great basalt plateaux of North-Western Europe in early Tertiary times. These plateaux formed a continuous tract of land, as far as the Faröes at any rate. He proves that in many places, such as Iceland, the Faröes, and the West of Scotland, enormous subsidence subsequently took place.[2]

Once we admit that animals and plants were able to survive the Glacial period in northern latitudes, a land-connexion such as suggested in Pliocene times would readily account for the presence of all the animals and plants common to Europe and America. By many of those best able to judge, an admission to that effect has been made. Pliocene deposits are scanty in the British Islands; yet they yield valuable suggestions as to the geographical conditions of the North Atlantic. An examination of the fossil invertebrates contained in the St. Erth Beds in Cornwall, which are of Pliocene age, showed that the fauna possessed a remarkably southern facies, and that there was

[1] W. Boyd Dawkins, *Early Man in Britain*, 1880, p. 43.

[2] A. Geikie, "Basalt Plateaux of North-Western Europe": Q.J.G.S., 1896, lii, p. 105.

a total absence of boreal or Arctic species. This fact led Professor Kendall and Mr. Bell to the conclusion that at the period during which these deposits were laid down—that is to say, during the latter part of the Pliocene period—no channel or direct communication existed between the North Sea and the Atlantic Ocean, the Straits of Dover being closed in the south, while in the north the Tertiary volcanic chain formed a barrier across from the North of Scotland to Greenland by way of the Shetland Islands, Faröes, and Iceland.[1]

Mr. Reid's contention that the St. Erth Beds are older than Messrs. Kendall & Bell estimated—that they are, in fact, of early Pliocene age—is founded chiefly on the circumstance that the percentage of extinct species is about the same as that of the Coralline Crag. The consideration of the supposed climatic conditions does not seem to me of any particular value; and, as he remarks, the exact age of the clays is still doubtful.[2] Even if the St. Erth Beds belong to the lower Pliocene, there are no grounds for the supposition that the northern barrier, alluded to by Messrs. Kendall & Bell, had ceased to exist in later Pliocene times.

The change in the Pliocene fauna of the east coast of England, as we pass from the older to the newer beds, no doubt implies, as Mr. Harmer pointed out, an opening up of the area to the influence of the northern seas.[3] But we do not possess the slightest evidence for the assumption that the Atlantic Ocean was similarly affected. Many of the facts, indeed, lead to the conclusion that the land on the Atlantic coasts of the British Islands stood highest in late Pliocene and early Pleistocene times, and that it was then that *Helix hortensis* and many other European species must have made their way to America.

Glacial conditions prevailed at this time on all the high mountain ranges surrounding the warm Atlantic Ocean, and yet the coast region must have supported an abundance of animal and plant life. The presence of a land-bridge between Scotland and North America by way of Greenland, and another between England and France, would have excluded the Gulf Stream from the Arctic regions. Professor Blytt's argument that under such conditions all the coast region, including Iceland and Southern Greenland, would have had a higher temperature than at present, while the lands beyond were probably colder, seems irrefutable.[4] Yet Professor James Geikie believes that even the latter countries would then have had a more genial climate.[5]

In my opinion it was during this epoch, in Pre-Glacial times, that the interchange between the fauna and flora of North-Western Europe and North-Eastern America was effected across the northern land-bridges.

Only one other point needs to be commented upon. I have shown

[1] P. F. Kendall & A. Bell, "The Pliocene Beds of St. Erth": Q.J.G.S., 1886, xlii, pp. 206, 207.

[2] C. Reid, *Pliocene Deposits of Britain*, 1890, p. 61.

[3] F. W. Harmer, "Pliocene Deposits of Holland": Q.J.G.S., 1896, lii, p. 754.

[4] Abel Blytt, "Theorie d. wechselnden Klimate": Engler's *Botanische Jahrb.*, 1881, ii, p. 49.

[5] James Geikie, *Prehistoric Europe*, 1881, p. 520.

that most of the American species occupy the Atlantic coast region in the British Islands. Almost all the southern or Lusitanian species are found in precisely the same area in England, Ireland, and Scotland. This seems to me partly due to the fact that the temperature was considerably higher there during the Glacial period than in the more inland localities. Even now the plants are under more favourable climatic conditions on the west coast than further inland, and less exposed there to competition with the stronger eastern rivals. Moreover, almost the whole of Ireland and a large portion of England are thickly swathed in a mantle of Glacial clay. We can only suppose that the forces which controlled the deposition of this clay were less effective on the west coast, which may have extended far to the west of its present boundary, and have thus given rise to the preservation of many species of animals and plants which were destroyed elsewhere.

REVIEWS.

I.—Geological Survey of Great Britain.

1. The Geology of the Seaboard of Mid Argyll, including the Islands of Luing, Scarba, the Garvellachs, and the Lesser Isles, together with the northern part of Jura and a small portion of Mull. By Dr. B. N. Peach, F.R.S., H. Kynaston, and H. B. Muff [Maufe]; with contributions from S. B. Wilkinson, J. S. Grant Wilson, J. B. Hill, A. Harker, F.R.S., E. B. Bailey, and petrological notes by Dr. J. S. Flett. 8vo; pp. vii, 121, with 7 text-illustrations and 8 plates. Glasgow, 1909. Price 2*s.* 3*d.*

WE cannot refrain from a feeling of sympathy with librarians, who give cross-references in their catalogues, at the lengthy title and array of authors and contributors imprinted in this memoir. The field-work, however, has been carried out by many hands in a very diversified region, comprising a number of islands and parts of islands, together with the western seaboard of Argyllshire, from Easdale and Kilmelfort on the north, to the plateau beyond the Crinan Canal on the south.

Nearly the whole of the area described is made up of various metamorphic rocks, including the Craignish and Ardrishaig Phyllites, the Easdale Slate and Limestone Group, and the Quartzite Group, together with epidiorites. No less than fifty-two pages are given to the description of these rocks, and of the folding, metamorphism, the crush-conglomerates, and thrust-planes; while the subject is illustrated by remarkable photographs of pseudo-conglomerate and strain-slip cleavage, of folds, boulder-beds, and phacoids of epidiorite.

Rocks of Lower Old Red Sandstone age occur on the mainland north of Loch Melfort, and in the islands of Seil and Lunga; and they consist mostly of andesitic lava-flows, with here and there some shales, grits, and conglomerates, as well as tuffs and agglomerates. There occur also masses of diorite and granite, together with dykes and sills of other intrusive rocks, and these, with the effects of contact metamorphism, are duly described.

Brief reference is made to the Tertiary igneous rocks of Mull, which comprise basaltic lavas, for the most part amygdaloidal, and intrusive sills of olivine-dolerite, that make strong features and possess columnar jointing. Dykes of Tertiary dolerite and basalt are numerous throughout the entire area; and these, which are described in some detail, include teschenites, tholeiites, andesitic pitchstone, and camptonite. Altogether, with the chapters on Old Red and Tertiary rocks, the petrographical portion of the memoir extends over eighty pages.

The higher grounds on the mainland, though glaciated, are comparatively free from superficial deposits, but evidence is given of the westerly seaward passage of an ice-sheet, which at one time filled the sounds and sea-lochs and overrode the outer islands, rising in Scarba and Jura in places to a greater height than any part of the mainland. Numerous small freshwater lochs occupying rock-basins owe their origin to the ice-erosion.

Raised beaches indicate that the area has undergone periodic elevation since Glacial times to the extent of about 100 feet; but it is mentioned that the contour-lines, which are continued "to a depth of 200 feet below Ordnance datum level, show that the floors of the different sea-lochs, and of the Sounds of Luing, Shuna, and Seil are studded with basins which, were the land upheaved to the extent of 200 feet, would form lochs much larger in area than any existing on the present land surface".

The inference is that the land was elevated to that extent or more during the Glacial period, and subsequently depressed, so that despite the final elevation of 100 feet, indicated by the Raised Beaches, "the promontories, islands, and skerries represent the hill-tops and dividing ridges between the drowned valleys."

The chapter on economics contains an important account by Mr. Maufe of the roofing-slates of Easdale, which have been systematically worked since 1748. It is interesting to note that while most of the best slates are characterized by small cubes of pyrites, some of the slates in which the iron sulphides are in a finely disseminated state are liable to decay.

2. The Geology of the South Wales Coal-field. Part I: The Country around Newport, Monmouthshire. By Aubrey Strahan, Sc.D., F.R.S. Second Edition. 8vo; pp. x, 115, with 6 text-illustrations and 1 plate. London, 1909. Price 1*s.* 6*d.*

TEN years have elapsed since we called attention (Geol. Mag., 1900, p. 86) to the first edition of this memoir, which was also the first publication relating to the re-survey of the geology of the South Wales Coal-field. The six-inch survey of the great coal-field, commenced in 1891, has been conducted and now completed under the personal superintendence of Dr. Strahan.

In this second edition of the Newport memoir the geological information relating to the area has been brought up to date; and of especial importance are the records of new coal-borings. A useful map has been added showing thicknesses of the Pennant Grit and Lower Coal Series at different localities.

In the former edition of the memoir attention was called to the

sharp plane of demarcation between the Silurian and Old Red Sandstone. It is now known that the Tilestones (passage-beds) and underlying minor Silurian divisions, met with 40 miles further west, are not present in the Usk district, unless represented by strata of wholly different characters. The list of Silurian fossils has been revised, and the nomenclature in the earlier edition modified in a way that may be said to render comparisons odious.

The Old Red Sandstone is now separated into Upper and Lower divisions, with the Brownstones in the upper part; but no evidence of unconformity in the formation has been detected.

Some observations have been made by Mr. E. E. L. Dixon on the zonal divisions in the Carboniferous Limestone of the Newport area, and the absence of the higher portions of the Limestone Series is attributed to the unconformable overstep of the Millstone Grit.

II.—Cretaceous of Poland.

FROM a series of papers extracted from *Kosmos* (Lemberg), 1909, vol. xxxiv, we gather that Jan Nowak describes the Cephalopod fauna of the uppermost Senonian (Campanian) of the Carpathians. The fauna was collected by Professor R. Zuber in Galicia and includes such well-known forms as *Baculites anceps*, Lam., *Scaphites constrictus*, Sow., *S. tenuistriatus*, Kner, and *Belemnites bipartitus*, Bl. With these occurs a form called "*Inoceramus Cripsi*, Mant." This unfortunate species seems to give endless trouble to Continental authors, and it may as well again be stated that the type in the British Museum is an internal cast, without any shell whatever, and came from the Chalk Marl of Offham. In England it is certainly a Cenomanian fossil, and there is nothing like it in the higher beds. Dr. Zuber describes the stratigraphy and tectonics of the Galician Carpathians in the same volume, and after an appropriate summary of previous authors, gives a lucid sketch of the geology, illustrated with many sections. But here also *Inoceramus Cripsi* is associated with *Belemnitella mucronata*, which seems an impossible thing to those who know the fauna of the Chalk of England. Dr. W. Rogala, who discusses this very point in a communication to the same volume, says on p. 742 of his paper: "Wszystkie formy z Lopuszki W. dadza sie pomiesoic w obrebie gatunku *Inoceramus Cripsi*, Mant., jaki temu gatunkowi nadal Zittel. Nowsze jednak badania Petraschecka wykazuja, ze formy gosawskie sa weale rozne od oryginalu Mantell'a, a badania J. Bohma wykazuja rowniez, ze i formy Goldfussa sa od niego rozne; wobec tego obydwaj ci autorowie nazwe *I. Cripsi*, Mantell zaciesniaja, a liozne formy dotychczas nia obejmowane oddzielaja jako osobne gatunki," and omits *I. Cripsi*, Mant., from his list on p. 745, using the name *I.* (cf.) *regularis*, d'Orb., instead.

Other interesting papers in this volume are on the fish fauna of the menilit-beds (Lower Oligocene) of the Carpathians, by Jan Rychlioki, and one on the Titonian Klippen at Kruhel Wielki, near Przemysl, by Dr. Zuber. These seem to be composed of foundered Inoceramus-bed, with exotic blocks of Stramberger Titonian.

C. D. S.

REPORTS AND PROCEEDINGS.

November 17, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Geology of Nyasaland." By Arthur R. Andrew, F.G.S., and T. Esmond Geoffrey Bailey, B.A., F.G.S. With a Description of the Fossil Flora, by E. A. Newell Arber, M.A., F.G.S.; Notes on the Non-Marine Fossil Mollusca, by Richard Bullen Newton, F.G.S.; and a Description of the Fish-Scales of *Colobodus*, etc., by Ramsay Heatley Traquair, M.D., F.R.S., F.G.S.

(1) The greater part of Nyasaland consists of crystalline rocks, which comprise—

(*a*) Highly metamorphosed sedimentary beds, including graphitic gneisses with limestone, and muscovite-schists.

(*b*) Foliated igneous rocks, especially augen-gneiss, derived from granite or syenite.

(*c*) Plutonic intrusions, usually granite or syenite, more rarely gabbro. In two localities nepheline and sodalite-syenites are found; these are perhaps of the same age as the similar post-Waterberg and pre-Karoo syenites of the Transvaal.

(2) In the north-western corner of Nyasaland is a somewhat altered sedimentary series, which forms the Mafingi Hills. It consists of a thick accumulation of quartzites, grits, and sandstones of pre-Karoo age.

(3) The Karoo System is represented both in the north and in the south of Nyasaland; in the north it occurs in patches, which owe their preservation to faulting. It has afforded remains of freshwater lamellibranchs (*Palæomutela*), fish-scales (*Colobodus*), and species of *Glossopteris*.

(4) Recent lacustrine marls and sands are found at great heights above the present level of the lake, and as much as 15 miles away from its margin.

(5) Pumiceous tuffs, associated with recent gravels containing pebbles of Tertiary lava, are found in the extreme north of the country; across the border, in German East Africa, Tertiary and recent lavas and tuffs are widely distributed.

(6) Nyasaland consists of high plateaux rising irregularly one above the other. The Nyika and Vipya plateaux were doubtless at one time continuous as "a platform of erosion", which originated after the main faulting of the Karoo in Northern Nyasaland, and before the formation of the great Nyasa fault trough.

2. "The Faunal Succession of the Upper Bernician." By Stanley Smith, M.Sc., F.G.S.

The Bernician Series forms the upper and by far the larger division of the Lower Carboniferous sequence of Northumberland, and covers the greater part of the county. Below the Bernician lie the Tuedian

Beds. The Northumberland succession, together with the Lower Carboniferous rocks north of the Tweed, occupies the northern extremity of the Pennine Province of the Carboniferous Limestone Series, which stretches from Staffordshire into Scotland. The Carboniferous strata in Northumberland encircle the Cheviots on the south, east, and north, and dip from the volcanic inlier, so that the general strike forms a rough semicircle round the igneous massif, nearest to which consequently lie the lowest beds.

The Bernician is mainly built up of sandstones and shales, but intercalated among the arenaceous and argillaceous deposits are the various beds of limestone and numerous seams of coal.

In the Upper Bernician, the limestones are fairly thick, are constant, and are truly marine. The calcareous beds of Lower Bernician age are thin and impure, and frequently contain *Stigmaria* and other plant-remains. There are a few good marine limestones, but these are of local occurrence.

The Upper Bernician, taking the Redesdale Ironstone Shale as the base, answers to Tate's Calcareous Group; while the Lower Bernician is equivalent to Tate's Carbonaceous Group.

It is with the Upper Bernician only that the present paper is concerned.

The whole of the Upper Bernician Limestones belong to the *Dibunophyllum*-zone, but they are capable of the following palæontological subdivisions :—

a = Redesdale Ironstone Shale.
Shallow-water fauna, mainly lamellibranchs ; corals rare.
Dibunophyllum near *θ* has been found.

I = Redesdale Limestone.
D 1 fauna.
Dibunophyllum θ.
Carcinophyllum θ especially characteristic.

II = Fourlaws and Oxford Limestones.
D 2.
Lonsdalia floriformis enters.

III = Eelwell, Acre, and Four Fathom Limestones.
D 2–3 presents in its main character a Zaphrentid phase.

IV*a* = Great and Little Limestones.
D 3.
Dibunophyllum muirheadi.
Koninckophyllum magnificum.
Diphyphyllum dianthoides.

IV*b* = Corbridge, Thornbrough, and Robsheugh Limestones.
The tendency in the Dibunophyllids towards Aspidophylloidal structure reaches its highest development.

IV*c* = Fell Top Limestone.
Characterized by the presence of *Dibunophyllum muirheadi* mut., cf. *Dibunophyllum ψ*, and *Phillipsastræa radiata*.

3. "Notes on the Dyke at Crookdene (Northumberland), and its Relations to the Collywell, Morpeth, and Tynemouth Dykes." By Miss M. K. Heslop, M.Sc., and Dr. J. A. Smythe. (Communicated by Professor G. A. Lebour, M.A., D.Sc., F.G.S.)

The dyke at Crookdene is exposed in the bed and banks of the

Wansbeck about 15 miles above Morpeth. It is intruded along a fault-fissure in beds of Bernician age, and apparently comes to a natural head. The basalt is characterized, microscopically, by narrow lath-shaped felspars and curved augites. Macroscopically, its most interesting feature is the occurrence of large inclusions of a felspar, which is shown by chemical analysis to be closely allied to anorthite. The exterior of the inclusions in contact with the ground-mass is strongly zoned, the latter showing a slightly chilled edge; the individual crystals are intergrown and are cracked, faulted, and in places completely shattered. In no case is the dislocation great, and, in fact, the crystals seem to have burst in situ. These phenomena point to a plutonic origin of the felspathic inclusions and connect them with the porphyritic felspars of the Tynemouth Dyke, for which a similar origin has already been suggested by Dr. Teall.

The dyke which comes to a head in the coast-section at Collywell, about 24 miles distant, shows almost precisely the same peculiarities. Chemical and microscopical examination of the two basalts and their felspathic inclusions show them to be practically identical. Considering these facts and the general field-relationships of the dykes, it appears probable that they belong to the same intrusion.

The work of Dr. Teall upon the dykes at Tynemouth and Morpeth has been amplified by further observations. The resemblances among the four dykes are so strong as to render it probable that they are derived from a common source. The observed differences are such as could be readily accounted for by differences of physical condition operating during the period of consolidation of the dykes.

December 1, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Tremadoc Slates and Associated Rocks of South-East Carnarvonshire." By William George Fearnsides, M.A., F.G.S., Fellow of, and Lecturer in Natural Sciences at, Sidney Sussex College, Cambridge.

This paper gives the results which have been obtained by the author in making a detailed map of the country about Portmadoc, Tremadoc, and Criccieth in Carnarvonshire, and describes the stratigraphy of the Cambrian and Ordovician rocks there exposed. The area described includes the original type-area of the Tremadoc Slates (Sedgwick & Salter), and the paper includes a detailed account of the local development of this well-known series.

The first part of the paper is devoted to a brief summary of the results attained by former workers, and is arranged to show the various stages through which the nomenclature of the major subdivisions of the Cambrian and Ordovician Systems have evolved.

The sedimentary series are described in the order of their formation. The succession may be tabulated as follows:—

	Western or Criccieth District.	*Eastern or Tremadoc District.*
Caradoc Series.	Rhyolitic ashes and agglomerates.	
	Variable dark-grey and black shivery slates, banded, but with no distinguishable horizons.	Grey slate series, often strongly banded, with a few shelly fossils (*Trinucleus* and *Orthis*) in the upper part.
		Andesitic ashes and ashy shales.
		Vesicular andesites.
Llandeilo Series.	Dark banded slates with intense cleavage; no fossils found.	Blue-black slates containing graptolites. Zone of *Nemagraptus gracilis*.
	Earthy slates, with occasional 'tuning-fork' graptolites.	
Arenig Series.	Shivery slates passing down into Flaggy grits yielding *Calymene parvifrons*.	
	Basal conglomeratic grit.	Conglomeratic grit of Ynys Towyn.
	Unconformity.	
Tremadoc Series.	Garth Hill Beds: Grey-blue slates with *Angelina*.	Not complete in the area studied.
	Penmorfa Beds: Flaggy mudstones and thinly-bedded slates, with *Shumardia* and the Shineton fauna.	
	Portmadoc Beds: Thickly-bedded felspathic slates, with occasional *Asaphellus*.	
	Moel-y-gest Beds: Banded grey slates and mudstones; few fossils, *Acrotreta* and *Bellerophon*.	
	The *Dictyonema* Band: A constant and characteristic band of bright rusting blue-grey mudstones, with abundant *Dictyonema sociale*.	
	Tynllan Beds: Thinly-bedded rusty shales with some hard grey mudstone bands, containing *Niobe* and *Psilocephalus*. (*Symphysurus*.)	
Dolgelly Series.	Sooty-black mudstones with *Peltura scarabæoides*.	
	Blue-black mudstone with *Agnostus trisectus*.	
	Black slates, with calcareous bands often crowded with *Orthis lenticularis*.	
	Dark flaggy slates with *Parabolina spinulosa*.	
Ffestiniog Series.	Grey-blue slates and flags crowded with *Lingulella davisii*.	
	Grey flags and grauwacké with some coarser bands (1800 feet thick).	
Maentwrog Series.	Rusty grey and blue slates, with thin bands of felspathic grauwacké.	

The folding, the cleavage, the faulting, and the jointing of the rocks are described, and an attempt is made to show some relationship between the various stress-phenomena which have produced these structures.

The great fault through Penmorfa is interpreted as a thrust-plane hading gently to the north-east. It is described as bounding two districts which are of a very different structural type, and is supposed to form the lowest sole of the group of thrust-planes which follow the southern margin of the Snowdonian mountain-tract.

The well-known pisolitic iron ore of Tremadoc is shown to follow the line of this fault, and is thought by the author to be of the nature of a metasomatic veinstone.

Direct evidence of overthrusting has been got from a study of the graptolite-bearing Llandeilo rocks of Tyddyn-diewm, which have been exposed in two artificial trenches dug for the purpose; and the distribution of the andesitic volcanic series in lines of detached lenticles among the Grey Slates is described as evidence of a similar reduplication of the newer series of the north-eastern district on a more extended scale.

The actual lines of major thrust-planes, other than the Pennforfa Fault, have not been discovered; but, from the broad-spreading character of the sills of gabbroid dolerite, the author infers that these have come in along the thrust-planes.

The petrographical characters of these quartziferous and hypersthene-bearing dolerites are not dealt with, but it is noted that the dolerites are (1) unaffected by cleavage and faulting; and (2) have metamorphosed rocks which were already cleaved, cut, and reduplicated by the thrust-faulting at the time of their intrusion: in this the author joins issue with previous observers in regard to their age.

The Glacial and post-Glacial accumulations are also described in outline.

2. "On some Small Trilobites from the Cambrian Rocks of Comley (Shropshire)." By Edgar Sterling Cobbold, F.G.S.

The majority of the trilobites noticed in this communication were obtained during the progress of some of the excavations referred to in the Report of the Geological Excavations Committee of the British Association, read at the Dublin Meeting, 1908.

The specimens were derived from the *Olenellus* Limestone of Comley, and from the Grey Limestones which intervene between that horizon and the Conglomeratic Grit yielding a *Paradoxides* fauna.

The author notices the occurrence of *Microdiscus lobatus*, Hall, *M. speciosus*, Ford, *M. helena*, Walcott, and *Ptychoparia* (?) *attleboroughensis*, S. & F. He describes eleven species, apparently new, which he refers to the genera *Microdiscus*, *Ptychoparia*, *Micmacca* (?), *Agraulos* (*Strenuella*), *Anomocare* (three species), *Protolenus* (two species), and two species to a new genus, to which Mr. Matthew's species *Micmacca* (?) *plana* may also be referred.

All the trilobites are represented by detached portions or fragments, often mixed indiscriminately, two or three species together, in the separate bands of rock; and the author adduces in some detail the evidence for correlating certain free cheeks, thoracic segments, and pygidia with the various head-shields, so that future workers may clearly distinguish between that which is actual fact and that which is a matter of inference.

3. "The Rocks of Pulau Ubin and Pulau Nanas (Singapore)." By John Brooke Scrivenor, M.A., F.G.S.

Pulau Ubin and Pulau Nanas are islands set in the eastern entrance to the Straits of Jahore, and consist of igneous rocks of considerable interest. Pulau Ubin is composed mainly of hornblende-granite, but

a pyroxene-bearing microgranite is found also; while the hornblende-granite is cut by rhombic-pyroxene bearing veins and also contains angular masses of rock resembling the veins.

The following grouping of the Pulau Ubin rocks (with which is included a rock found in the granite of Changi) is adopted.

I.

Normal hornblende-granite with a little monoclinic pyroxene.

II.

Pyroxene-microgranite with dark masses resembling III (i).

III.

(i) Porphyry, with peculiar spongy masses of hornblende.
(ii) Masses of a rock at Changi having the mineral constitution of an amphibole-vogesite.

IV.

(i) Veins of quartz-norite in the normal granite.
(ii) Veins and masses of enstatite-spessartite in the normal granite.
(iii) Masses of quartz-biotite-gabbro in the normal granite.

Pulau Nanas consists of dacite-tuffs and dacite which are referred to the Pahang Volcanic Series, of Carboniferous or Permo-Carboniferous age. The tuffs and lavas have been altered by the adjacent granite of Pulau Ubin, and contain much secondary biotite and hornblende. They also contain some fragments that appeared to be altered chert, but their most remarkable feature is the presence of fragments of altered granite.

The author discusses the mutual relations of the different rocks, and arrives at the following conclusions:—

(1) The normal granite of Pulau Ubin is hornblende-granite, the age of which is certainly post-Triassic and pre-Eocene, perhaps post-Inferior Oolite and pre-Cretaceous.

(2) Veins of quartz-norite and masses of quartz-biotite-gabbro, and veins and masses of a fine-grained rock which may be described as enstatite-spessartite, are found in the normal granite of Pulau Ubin. These point to an early differentiation of a granite and a gabbroid magma, perhaps in pre-Cretaceous times, and they are referable to rocks in Borneo and Amboyna.

(3) A pyroxene microgranite and porphyry on Pulau Ubin, and a rock at Changi, having the mineral constitution of an amphibole-vogesite, are described. Their relations to the other rocks are not clear.

(4) The dacite-tuffs of Pulau Nanas contain fragments of granite which must be of pre-Carboniferous age, and are referable to the granite of Amboyna.

(5) The fragments of granite, and perhaps certain pebbles of schorl-rock, are the only evidence found as yet in the Malay Peninsula of pre-Carboniferous rocks.

4. "The Tourmaline-Corundum Rocks of Kinta (Federated Malay States)." By John Brooke Scrivenor, M.A., F.G.S.

Overlying the limestone on the west side of the Kinta Valley is a thin cap of schists, with which are found certain rocks the two chief constituents of which are tourmaline and corundum. They are often carbonaceous; and, in the many variations found, white mica, brown mica, pleonaste, rutile, and metallic sulphides occur.

The tourmaline-corundum rocks contain certain structures which

are described in detail. These consist of round and oval cavities and bodies, the largest of which are about 6 millimetres in greatest width. Nothing can be proved regarding their origin, but the description of the rocks is summarized and a hypothesis adopted regarding their history, as follows :—

(1) The tourmaline-corundum rocks of Kinta consist of varying amounts of tourmaline, corundum, carbon, white mica, spinel, and other minerals.

(2) They contain cavities about 6 millimetres in greatest width, generally bordered by a layer of corundum grains, with tourmaline grains on the inside of this border. Sometimes solid bodies similar in size and shape to the cavities occur. They are composed of tourmaline and corundum, the former mineral, generally speaking, being more abundant towards the centre. Such bodies also show concentric structure.

(3) Smaller bodies occur, sometimes, but not always, accompanied by the larger cavities and bodies. They consist of tourmaline, of corundum, and of tourmaline and corundum. When both minerals are present, the corundum forms a shell to a nucleus of tourmaline. The corundum bodies frequently show concentric structure.

(4) The tourmaline-corundum rocks are associated with other rocks, which lead to the conclusion that the structures described in (2) and (3) are the result of replacement of the materials of pre-existing bodies at the time of extensive granitic intrusions.

(5) They also are associated with rocks which point to the original beds having been laid down under conditions similar to those that obtained when the Pahang Chert Series was deposited.

(6) As tourmaline-bearing partings in the limestone at Changkat Pari constitute a case of selective metamorphism, so it is thought that the tourmaline-corundum rocks as a whole mark a process of selective and intense metamorphism in beds associated with schists overlying the Kinta Limestone.

(7) These beds were probably chert and silicified limestone, both being in many cases carbonaceous.

(8) The larger cavities and bodies mentioned in (2) are believed to be the result of replacement or partial replacement of oolitic grains.

(9) The smaller bodies may be, in part, the result of replacement of the materials forming casts of radiolarian structures; in part, the result of the further development or replacement of spots seen in soft partings in the limestone at Changkat Pari; and in part, the result of the replacement of small oolitic grains.

OBITUARY.

HILARY BAUERMAN,

Assoc. M. Inst. C. E., Assoc. R. S. M., F. G. S.

Born 1833. Died December 5, 1909.

The closing days of the old year have gathered in another prominent geologist and fellow-worker to his well-earned rest, leaving our science the poorer, and ourselves to regret his loss. Of Hilary Bauerman's

early days we are not informed, but in 1851, at the age of 18, he became a student at "the Government School of Mines and of Science applied to the Arts", Jermyn Street, where he had the advantage of studying under Playfair, Ramsay, Forbes, Warington Smyth, Hunt, and Percy. It was specially due to the personal influence exercised by Dr. Percy and Sir Warington Smyth over the early students of the school that so many high classmen, like Bauerman, the Blanfords, F. Drew, Tookey, Sir C. Le Neve Foster, and many others, went forth to achieve high geological distinction in the world. From Jermyn Street Bauerman proceeded, in 1853, to the Freiberg Mining Academy, whence, after three years further study, he returned to England, and in 1856 accepted the post of an Assistant Geologist on the Geological Survey of Great Britain. But after three years work at home he was selected as geologist to the North American Boundary Commission, and during nearly six years he was occupied in most arduous survey work in Canada and the United States, including the delimitation of the Hudson Bay territory. Between 1863 and 1888 he was busily engaged in Government and professional work, mining and metallurgical surveys, and explorations abroad in almost every part of the world, save Australia and New Zealand. In 1883 he was appointed lecturer on metallurgy at Firth College, Sheffield, and still earlier (1874–9) was joint examiner in mining and mineralogy for the Science and Art Department.

His last official appointment (in 1886) was that of Professor of Metallurgy to the Ordnance College, Woolwich, from which he only retired in 1906, after some twenty years service. As a teacher, Professor Bauerman was particularly successful both with the cadets at Woolwich, who admired and revered him, and with the practical miners and metallurgists, including his workmen-students at the Firth College, Sheffield, and elsewhere, many of whom afterwards became his personal friends.

In addition to important papers read before learned and technical societies Professor Bauerman was the author of textbooks on *Descriptive Mineralogy* and on *Systematic Mineralogy*. But his name is best known perhaps in connexion with his classical work on the *Metallurgy of Iron*, and with the treatise on *Metallurgy* by Phillips & Bauerman. He was for many years a valued contributor to the columns of the *Engineer*, the *Mining Journal*, and other papers.

His extensive knowledge of chemical, mineralogical, and metallurgical subjects, and his experience as a teacher, led to his selection for the office of examiner for many years to the Civil Service Commissioners for the appointment of Mine Inspectors, to the Science and Art Department and the Board of Education in mining and metallurgy, and for a time in mineralogy also. He was likewise examiner of mining students to the Royal School of Mines and the Camborne School of Mines.

Few of the congresses at home or abroad passed without his presence. He was a member of the Metallurgical Committee of the Seventh International Congress of Applied Chemistry held in London this year, and president of a section of the Sixth Congress held in Rome, 1906; and most of our International Exhibitions had the benefit

of his experience as counsellor or juryman, from the Great Exhibition in 1851 to the Franco-British in 1908, on whose metallurgical section he wrote two excellent monographs, published by the Iron and Steel Institute.

Mr. Bauerman was elected a Fellow in 1863, and for nearly twenty years served on the Council of the Geological Society (from 1874 to 1898); he also filled the office of Vice-President. He was a most valuable referee on all scientific papers, and, like the late Professor Morris, his knowledge was encyclopædic both of men and subjects.

Bauerman's information was by no means confined to his own particular subjects, but extended over many sciences and arts. His interest in crystallography became an absorbing pursuit; and he found no greater delight than, with no appliances beyond an old envelope, picked out of the waste-paper basket, he would simply by deft folding, accompanied always by constant puffing and blowing, and many a joyful chuckle, develop some extraordinary figure in solid geometry.

Professor Bauerman was a member of many scientific societies both at home and abroad. He was elected an honorary member of the Chemical, the Metallurgical, the Institute of Mining and Metallurgy, and the Iron and Steel Institute. He was an associate member of the Institution of Civil Engineers, as an F.G.S. he for many years filled the office of Treasurer to the Geological Club, and was an associate of the Royal School of Mines. He received the Howard Prize from the Institution of Civil Engineers in 1897, and in 1906 was awarded the gold medal of the Institute of Mining and Metallurgy.

He was a perfect master of three languages, and being of an amiable disposition he always proved a most agreeable and interesting travelling companion, full of keen humour and geniality, so that throughout his life he attracted a large circle of warmly attached and admiring friends.

Professor Bauerman had been seriously ill for about ten weeks, but the immediate cause of his death, which took place peacefully on the morning of December 5, was heart failure. (See notices in the *Engineer*, the *Mining Journal*, *Iron and Steel Institute*, and *Nature*.)

MISCELLANEOUS.

Mr. O. T. Jones, M.A., B.Sc., of the Geological Survey of England and Wales, has been appointed Lecturer in Geology and Physical Geography in University College, Aberystwyth.

Mr. H. J. Seymour, B.A., of the Geological Survey of Ireland, has been appointed Professor of Geology in University College, Dublin.

Museum Destroyed by Fire.—The public library and museum at Kilmarnock has been destroyed by fire. The building, known as the Dick Institute, was presented to the town by the late Mr. James Dick, of Glasgow, about nine years ago. The museum contained the geological collection of the late Mr. James Thompson, F.G.S.; the destruction of which is much to be deplored.—*Times* (weekly ed.), December 3, 1909.